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PULP MILL SITES IN RELATION TO MILL
EFFLUENT EFFECTS ON WATER QUALITY
IN STREAMS IN WESTERN MONTANA AND
NORTHERN IDAHO

Public Health Service
Washington, D. C.

1955

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REPORT ON
PULP MILL SITES IN RELATION TO MILL EFFLUENT EFFECTS ON
WATER QUALITY IN STREAMS IN WESTERN
MONTANA AND NORTHERN IDAHO

PREPARED BY THE
WATER SUPPLY AND WATER POLLUTION CONTROL PROGRAM
PUBLIC HEALTH SERVICE, UNITED STATES
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

IN

COOPERATION WITH THE
MONTANA BOARD OF HEALTH
IDAHO DEPARTMENT OF PUBLIC HEALTH
AND THE
FOREST SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C.
1955

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III.
REPORT ON PROPOSED
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COLOR ILLUSTRATIONS REPRODUCED
IN BLACK AND WHITE



Figure 1 - Clark Fork River - One of the Streams West of the Continental Divide in Montana and Idaho Studied in Connection with the Proposed Developments of Pulp and Paper Mills in the Upper Columbia River Basin.

1.
PULP MILL SITES IN RELATION TO
EFFECTS ON WATER QUALITY IN WESTERN
MONTANA AND NORTHERN PART OF IDAHO

FOREWORD

This report summarizes information obtained in a preliminary study of suggested areas for possible location of pulp mills in the States of Montana and Idaho, west of the Continental Divide, considered from the possible effect of effluents on water quality in the Clark Fork, Pend Oreille, Flathead, Kootenai, Spokane and Clearwater Rivers in the Upper Columbia River Basin. The reconnaissance survey of contemplated mill sites, made in keeping with the request and interest shown by the Montana State Board of Health and the Idaho Department of Public Health, respectively, was undertaken during 1952. Sections of the streams covered, for convenience in discussion, have been designated as follows: Clark Fork above Missoula, Clark Fork from Missoula to St. Regis, Clark Fork from St. Regis to its junction with the Flathead, the Clark Fork and Pend Oreille below Plains, the Flathead River above the junction with the South Fork, Flathead River from the junction with the South Fork to Flathead Lake, Flathead River from Flathead Lake to junction with Clark Fork, Kootenai River from Newgate to Libby, Kootenai River from Libby to the Canadian Border, Spokane River below Coeur d'Alene Lake and above Post Falls, Idaho, the Clearwater from Kamiah to Spaulding and Clearwater below Spaulding. The Forest Service, Missoula office, U. S. Department of Agriculture, the Montana State Chamber of Commerce, as well as the above State health agencies, and other Federal, State and local agencies, are interested in the proposal to build pulp mills in the area, and participated in visits to sites considered or attended meetings and conferences arranged as a part of the survey. Subsequent to the initial observations made and gathering of information started in Montana and Idaho, supplemental data and material have been furnished by numerous individuals and agencies, which have been very helpful in studies conducted in preparation of this report.

ACKNOWLEDGMENTS

The assistance of Mr. C. W. Brinck and Mr. H. W. Taylor of the Division of Environmental Sanitation, Montana State Board of Health, and Mr. H. C. Clare, Director, Division of Environmental Sanitation and Mr. Aleck Alexander, Director, Water Pollution Section, of the Idaho Department of Public Health, in obtaining essential information and data used in this study is gratefully acknowledged.

The cooperation of the Missoula office, Forest Service, U. S. Department of Agriculture, in furnishing various facts relating to the contemplated pulp mill developments, especially the aid of Mr. S. Blair Hutchinson, is acknowledged with appreciation. Mr. G. H. Chidester of the Forest Products Laboratory has provided valued assistance. The Montana Power Company, through Mr. R. C. Setterstrom, furnished hydrologic data and other helpful information. Acknowledgment is also made to the Bureau of Reclamation, Fish and Wildlife Service, and Geological Survey, Department of Interior, Federal Power Commission, Montana Fish & Game Department, and the Missouri Drainage Basin Office, Division of Water Pollution Control, Public Health Service, Department of Health, Education, and Welfare, for assistance rendered in obtaining data, or information from their published reports, and for comments and suggestions made covering water storage and irrigation, stream discharges, power projects, existing pollution, and other items relating to developments in the Clark Fork, Pend Oreille, Flathead, Kootenai, Spokane, and Clearwater River Basins.

SUMMARY AND CONCLUSIONS

The findings from this survey are briefly as follows:

1. There are extensive timber resources west of the Continental Divide in the States of Montana and northern Idaho which are suitable for pulp manufacture. Consideration is being given to establishing pulp mills in this immediate area. Extent of pollution of the streams by the wastes from such mills is an important factor which must be given consideration.
2. Much of the pulpwood available is suitable for sulphate or kraft pulping. Although other type mills may be considered in the future, this survey or study is limited to generally evaluating the pollution effects of sulphate mills.
3. The introduction of pulp mill wastes into a stream will have some effect on the character or quality of the water in it. The important consideration is whether these changes will adversely affect existing and future desirable uses of the stream below the pulp mill and the extent or degree of any detrimental effects on such water uses.
4. It is expected that the minimum size mill to be established would have a capacity of 200 tons of pulp per day. The mill might be located on any sector of a stream which had adequate capacity to assimilate the mill wastes. The pollutional effect of the wastes from this size and in some cases larger mills has been approximated for all sectors of streams in the area that could possibly assimilate such wastes without undue detrimental effects.

5. Clark Fork above Missoula: The wastes from a 200 ton kraft pulp mill in the sector between the junctions with the Bitterroot and Blackfoot Rivers may occasionally reduce the oxygen concentration during periods of low flow somewhat below that considered desirable for the propagation of cold water fish. It is expected that toxic effects of the mill wastes on fish food organisms will tend to reduce the desirable fish populations for a limited distance below the mill. The mill effluent may necessitate appropriate treatment for removal of color, taste and odor from any public drinking supplies that are obtained in the future from a sector of the Clark Fork extending from below the mill outlet to some distance below Missoula. No present water supply will be affected. Effects on the esthetic quality of the stream will be limited to a relatively short sector below the mill. There should be no significant effect on the suitability of the water for irrigation. It is concluded from the presently available information and data that this sector of the stream is a less suitable site for a pulp mill than many of the others considered. It is believed that additional treatment or control of the wastes from a 200 ton pulp mill at this location beyond that normally practiced by such mills would be required to prevent any detrimental effect on the fish life in the stream.

6. Clark Fork River from Missoula to St. Regis: It appears that the wastes from a 200 ton kraft pulp mill would not reduce the dissolved oxygen concentration in the stream below that considered adequate for the propagation of fish. It is probable that there will be very little, if any, effect on the desirable fish populations. No present water supply will be affected. Taste and odor producing substances in the wastes may make the stream somewhat less satisfactory as a source for public drinking water supplies in a sector that may extend from the mill to a short distance below St. Regis. There will be no appreciable effect on the suitability of the water for irrigation use. Noticeable effect on the appearance of the stream will be limited to a relatively short sector below the mill waste outlets. It is believed that a 200 ton kraft pulp mill could be established in this sector without particular harm to other uses of the water. There is a considerable quantity of organic waste presently being discharged into the stream at Missoula. Although an attempt has been made to take this into consideration in making this estimate, it is extremely desirable that the actual effect of these wastes be determined by means of a stream survey before the plans for any proposed pulp mill in this area progress beyond preliminary planning.

7. Clark Fork from St. Regis to its junction with the Flathead: It appears that this sector of the Clark Fork can assimilate the wastes from a 300 ton kraft pulp mill. Even during periods of lowest flow the dissolved oxygen concentration should be appreciably above that required by fish. The dilution available is such that there should be little, if any, significant effect on the fish populations of the stream. Significant impairment of the water quality for use as a source of drinking water supply would be essentially limited to the sector below the mill and above the junction with the Flathead. Its suitability for irrigation purposes would not be affected. Except for the immediate vicinity below the mill waste outlets, the appearance of the water will be little affected.

8. The Clark Fork and Pend Oreille below Plains: It is believed that the flow in this sector is sufficient at all times to adequately assimilate the wastes from a 1,000 ton kraft pulp mill. The wastes will be diluted sufficiently so that any significant effect on the fish or other aquatic life in the stream would not be expected to occur. If the mill were located above Pend Oreille Lake, it is very doubtful whether there would be any noticeable tastes and odors in the water supplies of Sand Point or Priest River due to the pulp mill wastes. If it were located below Pend Oreille Lake and above Priest River it is probable that the Priest River supply would be affected sufficiently so that treatment for taste and odor removal would be necessary. Suitability of the water for irrigation use would not be affected. It is concluded from the available information that this stream sector could assimilate the wastes from a larger pulp mill than any of the other areas considered.

9. The Flathead River above the junction with the South Fork: The flows in this stream are relatively limited. Although the wastes from a 200 ton kraft pulp mill would not reduce the dissolved oxygen concentration below that required by the fish and aquatic life, there would be considerable reduction of desirable fish food organisms for an appreciable distance below the mill waste outlet. This factor, together with possible impairment of fish spawning areas by the wastes, would be expected to significantly reduce the desirable fish populations in the stream. The quality of the water will be less satisfactory as a source for drinking water supplies from below the mill waste outlet to Flathead Lake. Use of the water for irrigation would be unaffected. It is concluded from the information and data available that the wastes from a 200 ton kraft pulp mill would significantly pollute the stream unless unusually effective measures were taken to reduce or treat the wastes.

10. Flathead River from the junction with the South Fork to Flathead Lake: Future flows in this stream sector will undoubtedly be changed appreciably from what they have been in the past due to regulation of flows at Hungry Horse Dam. This may have a significant effect on the ability of the stream to assimilate the wastes from a kraft pulp mill. It is not known whether the recently constructed aluminum plant near Columbia Falls is discharging wastes into the stream which would affect its ability to assimilate the pulp mill wastes. Sufficient information was not available to evaluate the possible effects of these two installations. It is necessary that this be done before giving serious consideration to the establishment of a paper pulp mill in this sector.

If the aluminum plant wastes are not a significant factor and if the operations of Hungry Horse Dam do not reduce the future minimum winter and summer flows, it is believed that this sector of stream could assimilate the wastes from a 200 ton kraft mill. The mill wastes will have negligible effect on the fish or other aquatic life in the stream. The detrimental effects that the wastes might have on the suitability of the waters as a source for drinking water supplies would not be expected to extend below Flathead Lake. Use of the waters for irrigation should not be affected. This may be a comparatively suitable location for a 200 ton kraft pulp mill from the standpoint of waste disposal.

11. Flathead River from Flathead Lake to junction with Clark Fork: It appears from the information and data available that this sector of the stream may be expected to satisfactorily assimilate the wastes from a 400 ton mill. Any detrimental effects that the wastes would have on the suitability of the water as a source for drinking water supplies would probably not extend appreciably below the junction with Clark Fork. It is not now being used as a source of such supplies. It is believed that other pollutional effects would be negligible.

12. Kootenai River from Newgate to Libby: On the basis of stream flows which have occurred in the past it is estimated that this sector of stream can satisfactorily assimilate the wastes from a 300 ton kraft pulp mill. It is doubtful whether there would be any significant reduction of fish or aquatic life due to the wastes. As far as is known, the stream is not presently used as a source for public drinking water supplies. It is reported that Libby may use it as a source in the future. If the mill is located 25 stream miles or more above Libby, the taste and odor introduced into the proposed Libby supply would be expected to be noticeable only during some periods in the winter when the lowest flows occur. Such tastes and odors could be satisfactorily removed by appropriate water treatment procedures.

Mention has been made that Canada has been giving some consideration to diverting part of the flow from this stream at some future time. The possible effect of such diversions should be checked before proceeding with the establishment of a pulp mill on this stream.

13. Kootenai River from Libby to the Canadian Border:
An analysis of the available information and data indicates that this stream sector is capable of satisfactorily assimilating the wastes from a 400 ton kraft pulp mill. It is improbable that the wastes from such a mill would noticeably reduce the population of the fish of the stream. Its suitability for irrigation purposes would not be affected. Because of the relatively high flows during the summer period, the wastes would not cause significant taste and odor problems in water supplies which might use downstream sectors as their source during the summer period. Treatment for taste and odor might be required for such supplies during periods of low flows which occur in the winter.

Before definite consideration is given to the establishment of a mill in this sector, possible future upstream diversions in Canada should be investigated as well as potential stream use for public water supply at Bonner's Ferry.

14. Spokane River below Coeur d'Alene Lake and above Post Falls, Idaho: Much of the flow in this stream sector is diverted for irrigation during the summer and early fall. The stream flow below the points of diversion are inadequate during the summer and fall periods to assimilate pulp mill wastes. It is concluded from the available information and data that this sector is unsuitable for the disposal of pulp mill wastes.

15. The Clearwater from Kamiah to Spaulding: The unusual clarity of its water, together with other characteristics, gives this stream particular appeal to conservationists and sportsmen. It is concluded from the available information and data that this stream sector would not satisfactorily assimilate the wastes from a 200 ton kraft pulp mill. The wastes would have significant detrimental effects on all desirable water uses with the exception of irrigation.

16. The Clearwater below Spaulding: Available information indicates that there is considerable spawning by anadromous and other fish in certain reaches of this stream. It is probable that the wastes from a 200 ton pulp mill would noticeably affect the appearance of its naturally clear waters.

Considering the dilution available and other factors, it is believed that the wastes from a 200 ton kraft pulp mill could be discharged into this sector without significantly reducing the fish populations of the stream. With the possible exception of recreational use, the wastes would have relatively little effect on the suitability of these waters for other uses. Because of the natural clarity of the water, it is expected that the wastes will be noticeable in the stream to a degree that may be objectionable to conservationists and sportsmen. This is a factor to take into consideration in determining whether or not to locate a pulp mill along this stream.

17. It is recommended that as a part of future planning for any pulp mill projects in this area, there be included complete stream surveys of those portions of the rivers that may be significantly affected by the wastes. The purpose of these surveys would be to determine as accurately as possible existing physical, chemical, biological and other factors that would govern mill production capacity in relation to waste disposal at each specific site.

GENERAL INFORMATION

Request:

At the request of the Montana State Board of Health and the Forest Service, U. S. Department of Agriculture, the Public Health Service had previously conducted a study making preliminary estimates of the probable effect of pollution which would result from the establishment of sulfate pulp mills at several locations east of the Continental Divide in Montana. Findings of the above study were reviewed at a conference in the offices of the Montana State Board of Health on August 13, 1952. In addition to representatives of the Montana State Board of Health and the Public Health Service, there were present at the meeting: Mr. R. C. Setterstrom, Industrial Engineer of the Montana Power Company and Industrial Development Chairman of the Montana Chamber of Commerce; Mr. William H. Browning, Secretary of the Montana Chamber of Commerce; Mr. S. Blair Hutchinson, Forest Service, U.S.D.A.; Mr. Walter M. Allen, Superintendent of Fisheries, Mr. W. E. Thompson, Director of Public Relations Division, and Mr. Robert F. Cooney, Director, Wildlife Restoration Division of the Montana Fish and Game Department.

During this conference it was indicated that similar information was also needed for that part of Montana west of the Continental Divide. The Forest Service expressed the desire

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Figure 2 - Water From the Clark Fork River is Being Utilized for Irrigation of Crops and for Industrial Water Supply: View Shows Spray Irrigation Near Missoula, Montana With Pulp Mill Plant in the Background.



Figure 3 - Clark Fork River Upstream from Superior, Montana. This Fast-Flowing Stream is Used for Sport Fishing. Note Anglers Along the Far Shores.

that portions of northern Idaho be included. Agreement was reached that a survey and study similar to the previous one be made for these areas subject to concurrence of the Idaho Department of Health with respect to the sectors of Idaho involved. This concurrence was subsequently received.

Purpose:

The purpose of this study is to make a preliminary estimate from the existing available data of the extent and effects of pollution which would result from the establishment of sulfate pulp mills along various sectors of streams in western Montana and northern Idaho. It is intended to serve only to indicate the approximate pollutional effects expected at the various locations for the purpose of determining whether additional consideration and study of certain sites is justified.

FIELD WORK

Arrangements generally outlined by the Montana State Board of Health provided for the inspection of those areas and stream sectors considered as possible sites for future pulp mills in western Montana. The field work involved observations of the characteristics of the streams at numerous locations. The trip, during the period of August 13-18 inclusive, included a number of meetings and conferences for developing background information in connection with this preliminary survey of possible stream pollution effects from pulp mills at the sites under consideration. Similar procedures as arranged by the Idaho Department of Health and others interested were followed with respect to the portion of Idaho streams studied.

Survey Group:

Those participating in the survey of Montana sectors were: Mr. C. W. Brinck, Director, Division of Environmental Sanitation, Montana State Board of Health; Mr. Walter M. Allen, Superintendent of State Fisheries, Montana State Fish and Game Department; Mr. S. Blair Hutchinson, Forest Economist, U. S. Forest Service; Mr. R. S. Setterstrom, Industrial Development Engineer of the Montana Power Company; and Mr. L. F. Warrick of the Public Health Service. During that portion of the trip in the Kalispell and Polson areas, Mr. A. W. Clarkson represented the Montana Board of Health for Mr. Brinck and Mr. F.A. Stefanich represented the Fish and Game Department for Mr. Allen. Mr. Aleck Alexander joined the survey group for the meeting at Sandpoint, Idaho as representative of the Idaho Department of Health.

Procedure:

The stream sectors along which mills might be located were inspected at the conveniently accessible locations. Interested local citizens accompanied the survey group on some of these inspections. Officials and other local personnel were contacted for needed data or information and prearranged meetings held with representatives of local groups. The object was to promote the maximum interchange of information on all aspects of the pulp mill projects, particularly as they related to the effects of mill effluents on quality of surface waters.

Inquiry was made into the water uses in the area, covering municipal, industrial, agricultural, recreational and other interests involved. The anticipated future developments as well as current construction that might influence consideration of sites were reviewed. Data obtained along with that furnished by the State Health Departments and other official agencies provided needed background for studies covered by the report.

Travel within and between the sectors under consideration was accomplished by automobile which made it possible to observe flow conditions at a number of locations on each of the streams involved. Particular attention was directed to determining whether turbulent or quiet flow existed in specific reaches of the streams, which was needed to make estimates of the stream aeration and oxygen resources available for oxidation of such wastes as would be discharged from pulp mills.

Contacts were made with the operating staff of a number of power plants for available information relating to stream flow, flow regulation and water temperatures. The Montana Power Company substantially aided the survey by providing an important part of this type of data.

Attendance at Meetings:

The survey group contacted the following individuals at meetings that were scheduled along the route followed in the field work.

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Figure 4. - Clark Fork River between St. Regis and the Mouth of the Flathead River.



Figure 5 - Alberca Falls Dam under Construction by The Corps of Engineers along the Pend Oreille River Near the Idaho-Washington Boundary; Outstanding Progress is Being Made. Development of Hydroelectric Power Potentials of the Upper Columbia River Basin.

Persons attending the noon meeting at Missoula on August 14
were:

H. O. Bell, H. O. Bell Co., Missoula
Bill Browning, Montana Chamber of Commerce, Helena
L. E. Bunge, Missoula Mercantile Co., Missoula
H. W. Camp, Jr., U. S. Forest Service, Missoula
O. E. Coffee, Missoula Drug Co., Missoula
Les Colby, Missoula Mercantile Co., Missoula
M. E. Dixon, KGVO, Missoula
Pat M. Goodover, KXLL, Missoula
Sid F. Howard, Florence Lumber Co., Missoula
H. H. Koessler, Intermountain Lumber Co., Missoula
Jack Lubrecht, Missoula
L. A. MacDonald, N.P.R.R. Co., Missoula
Bob McCann, Missoula Chamber of Commerce, Missoula
Harry McCann, Montana Power Co., Missoula
M. B. Morrow, Missoula
A. J. Mosbey, KGVO, Missoula
Don Paddock, Attorney, Missoula
H. C. Pauly, Lawyer, Missoula
H. F. Jack Root, A.C.M. Co., Lbr. Dept., Missoula
R. Roth, N.P.R.R. Co., Missoula
Wm. Steinbrenner, Jr., Missoula Brewing Co., Missoula
Art Strom, Montgomery Ward, Missoula
H. W. Taylor, State Board of Health, Helena
J. W. Toole, Insurance, Missoula
D. M. Warren, Intermountain Lumber Co., Missoula

An evening meeting was held in St. Regis on August 14.
Local persons attending were:

J. L. Alexander, St. Regis
W. Warren Ensign, Forest Service, St. Regis
E. J. Krekian, St. Regis
Otto F. Krekian
Russell W. Mainwaring, St. Regis
Sherman Miller, St. Regis
W. E. Sears
W. Bert Waldron, Forest Service, St. Regis
Earl P. While, St. Regis
Ernest P. White

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Figure 6 - Sport Fishing is an Important Asset in Attracting
Tourists to Montana and Idaho.

The following were present at the noon meeting held in Thompson Falls on August 15:

P. B. Banister, First State Bank, Thompson Falls
C. A. Baxter, Wood Working Plant, Thompson Falls
A. H. Cheney, Fish and Game Comm., Thompson Falls
Henry L. Gill, Garage Owner, Sportsman, Thompson Falls
Ed Hazelton, Co. Comm., Paradise
W. C. Klockler, Montana Power Company, Thompson Falls
O. J. Murray, Rancher, Thompson Falls
H. E. Smith, County Comm., Hot Springs
M. C. Sutherland, Co. Comm., Thompson Falls

On the evening of August 15 a meeting was held at the high school in Sandpoint, Idaho. Mr. Aleck Alexander represented the Idaho State Department of Health. Attending were municipal representatives, members of the Sandpoint Chamber of Commerce, local health officials and other interested individuals from the immediate locality.

The following persons from Libby attended the meeting held near there on the night of August 16:

Howard E. Ahkhoy, U. S. Forest Service
Ed Boyes, Chairman, Fish and Game Commission
Paul E. Church
Daniel Combest, KLCB
Paul H. Logan
Leo Lyser
Arthur J. Neils, J. Neils Lumber Co.
Donald R. Roberts
Paul J. Seifert, Jr., M.D., Libby Chamber of Commerce
R. R. Veldman, J. Neils Lumber Co.

A relatively large number of local people attended the noon meeting held in Kalispell on August 18. Following is a list of the individuals present:

Fred Brinkman, Kalispell
R. W. Carr, Kalispell
Merl Ebbe, Kalispell
Jim Foulds, Kalispell
Neil Fritch, M.D., Kalispell
M. F. Gould, Kalispell
S. M. Halvorson, Kalispell

J. H. Hawkins, Kalispell
Matt Hernal, Kalispell
Bert Johnson, Kalispell
H. B. Markus, Whitefish
Clark Mason, Chamber of Commerce, Kalispell
A. E. Massman, Columbia Falls
Hans Nebust, Kalispell
G. M. Moss, Whitefish
Walt Mauritsen, Kalispell
J. Neitaling, Kalispell
Lillian Hibb, Kalispell
H. G. Preston, Columbia Falls
Merle Rawlings, Kalispell
Mel Ruder, Columbia Falls
L. E. Scott, Whitefish
Brad Seely, Whitefish
J. R. Stevens, Kalispell
Ed Stockton, Kalispell
L. P. Tomer, Martin City
Bob Turman, Flathead Sports Assn., Kalispell
H. E. Van Allen, Whitefish
S. E. Wagner, Kalispell
R. O. Waller, Kalispell
Merritt N. Warden, Kalispell

The following persons attended the meeting held at Polson on the night of August 18:

Chauncy Biffle, State Emp. Ser., Ind. Com., Polson
L. A. Campbell, Sec., Polson
Frank Emory, Retired, Pulp and Paper Company, Polson
Geo. Fitzgarrald, Wholesale Oil & Gas, Ind. Com., Polson
Fred McConnell, Laundry - Pulp and Paper Company, Polson
Frank Maxam, The Ranch, Board of Directors, Polson
Eddie Pinkney, Drugs - Ind. Com., Polson
Wm. Rader, Local Paper - Ind. Com., Polson
Leo Sensabough, Polson Mill - Ind. Com., Polson
M. J. Sterne, Former Highway Department Eng., Ind. Com., Polson

The contacts in Idaho during inspection trips in the Clearwater and Coeur d'Alene river basins were made in company with officials of the Idaho Department of Health and members of the Idaho Water Resources Advisory Committee. In 1952, Governor Len B. Jordan appointed this Committee to study water problems of the State.

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Figure 7 - Kootenai River at Libby, Montana, Downstream from the Site of the Proposed Libby Dam and Power Plant.



Figure 8 - Kootenai River at Bonners Ferry, Idaho. Possible Future Source of the Municipal water Supply.

Members were:

L. J. Peterson, Director, State Department of Public Health,
Boise (Chairman)
Harry Marsh, Secretary, Idaho Mining Association, Boise
Leon Jones, J. R. Simplot Co., Caldwell
Harry Elcock, Manager, Amalgamated Sugar Co., Twin Falls
Earl Bullock, Potlatch Forests, Inc., Lewiston
J. E. Cushman, President, State Chamber of Commerce, Preston
Bruce Bowler, Boise
Dr. W. L. Jacobs, Lewiston
Professor L. C. Cady, Director of Research, University of
Idaho, Moscow
T. B. Murray, Idaho Fish and Game Commissioner, Boise

Arrangements for meetings and contacts were made by H. C. Clare, Director, Division of Environmental Health, Idaho Department of Public Health. E. F. Eldridge, Director and Chief Engineer, State of Washington Pollution Control Commission, attended the meeting held August 9, with officials of Potlatch Forest Industries, Inc., and their advisor on water pollution, Dr. Willis Van Horn, Biologist, Institute of Pulp and Paper Chemistry, Appleton, Wisconsin; and also participated in an inspection trip through the Potlatch Forest Industries pulp and paper mill at Lewiston, Idaho.

In the Coeur d'Alene river basin, a meeting was held August 11, at Wallace, Idaho to discuss water problems. This meeting was devoted largely to mining waste problems. There was a total of 58 people in attendance, most individuals present being representatives of mining corporations operating in Idaho.

Representatives of the Public Health Service participating in trips in both the Clearwater and Coeur d'Alene River Basins in Idaho were Carl E. Schwob, L. F. Warrick, R. R. Harris, and W. Q. Kehr. All took part in the meetings at Lewiston and Wallace.

Added to those in attendance at the meetings in Montana and Idaho, there were a number of individuals talked with along the route of the reconnaissance survey of potential mill sites who furnished data and information of assistance, and who provided background concerning local views on proposed developments.

Areas Involved:

The areas involved in the survey, all situated in the Upper Columbia River Basin, have been increasingly looked upon with interest as potential sites for pulp and paper mills. The first mill was built in 1950 at Lewiston, Idaho, just above the junction of the Clearwater and Snake rivers. In recent years, steps were taken to organize a company to build a mill in the vicinity of Polson, Montana.

There is considerable pulpwood timber along all of the streams west of the Continental Divide in Montana and northern Idaho. Only a limited amount of the available pulpwood is presently being harvested, which is either being exported to mills in the midwest or utilized in the existing mill at Lewiston. The pulpwood available, including a considerable amount of blight damaged timber in addition to the expected annual crop of green wood, is sufficient to very adequately support operations at several mills located west of the Continental Divide. There is a desire to use a substantial part of the potential annual pulpwood production of these forest areas as a raw material for pulp manufacturing operations within the area.

In view of the general availability of pulpwood resources, it was suggested that study be given to possible locations of pulp mills along all stream sectors which would have the capacity to assimilate the mill effluent without causing undue harm to other existing or expected future beneficial uses of the waters. In this study, consideration has been given to the capability of all streams in the Clark Fork, Pend Oreille, Flathead, Kootenai, Clearwater, and Spokane River Basins in Idaho and Montana to satisfactorily assimilate the wastes from a 200 ton or larger sulphate pulp mill.

The river basins are shown in color on the map included in the appendix of this report. The Clark Fork River Basin, shown in yellow, includes a substantial portion of Montana west of the Continental Divide. It is a relatively sparsely populated area having mineral deposits, forests, agricultural lands and water resources which are not as yet being extensively utilized. Much of it is made up of conifer forested mountains. The pleasant summer climate, natural scenery, forests, streams and lakes contribute to making recreation probably the most valuable industry in the basin.

Water resources of the basin are substantial. It is reported that existing pollution damages are confined principally to the stretches of the Clark Fork below Butte and Missoula, Montana; Whitefish Creek at Whitefish, Montana; and Ashley Creek below Kalispell, Montana (1). Figures 1, 2, 3, and 4 illustrate the natural beauty and some of the present uses of the Clark Fork.

That portion of the Pend Oreille Basin in Idaho is shown in brown on the map. Figure 5 shows a view of the Albion Falls Dam while under construction. This dam, near the Idaho-Washington boundary is a unit in the development of hydroelectric power in the upper Columbia River Basin. There is a very substantial quantity of flow in the Pend Oreille river. It is reported that damaging pollution existing in this portion of the basin is confined to a stretch of the Pend Oreille below Sandpoint (1).

The Flathead River Basin is a sparsely settled area consisting in substantial part of coniferous forested mountains. It includes the

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Figure 9. - Mining and Ore Beneficiation are Important Industrial Activities Near the Headwaters of the Coeur d'Alene River.



Figure 10 - Sediment from Mining and Processing of the Ore is Dredged from the Coeur d'Alene River.

northern portion of Montana immediately west of the Continental Divide. The extensive forest resources are not presently utilized to a great extent except as they contribute to the recreational attraction of the area. The relatively clear and fast flowing streams of this basin together with other attractions make recreation a major industry of the Basin, Figure 6. Of these, only the portion of the Flathead below the junction of the South Fork has sufficient flow to justify its consideration as a location for a pulp mill.

The portion of the Kootenai River Basin under consideration includes the northern tip of Idaho and the extreme northwestern part of Montana. The area consists principally of rugged mountains with narrow valleys. Fertile soil in the valleys, huge timber resources and mineral deposits, have led to some farming, lumbering and mining in the area. There is relatively little use of the water and other natural resources of the area. Probable future use of the river at Bonners Ferry, Idaho, as a source of public water supply has been indicated. The Kootenai River is characterized by high summer flows and is more turbid than the other streams considered in this study. Views of the Kootenai River are shown in Figures 7 and 8.

Approximately the upper two-thirds of the Spokane River Basin is located in northern Idaho which is the only part considered in this study. There are rather extensive mining operations in the headwaters area, particularly along the south fork of the Coeur d'Alene River. Tailings from the ore concentration mills have been a cause of pollution of the Coeur d'Alene. Steep valleys, as shown in Figure 9, are conducive to flash floods. In addition to causing extensive property damage, periodic floods of this river have washed impounded tailings down the lower Coeur d'Alene Valley. Figures 9, 10, and 11 illustrate mining operations of this sector and some of the associated waste disposal problems. A very large portion of the flow in the sector of the Spokane River immediately below Coeur d'Alene Lake is diverted for irrigation of the very fertile downstream agricultural areas.

There is significant agricultural production on farm lands in the lower portion of the Clearwater Basin. Much of it is good grain or dry crop producing area and only a limited proportion is irrigated. A large portion of the basin contains stands of select white pine, spruce, cedar and other coniferous species. Much of the forest area is rugged and the timber is presently inaccessible for harvesting. The largest logging activities are currently in the North Fork Basin with logs and pulpwood delivered by water or rail to mills at Lewiston and some other points in the Basin. Figures 12, 13, 14, and 15 are views of the scenic Clearwater River and lumbering and paper pulp manufacturing operations in the basin.

The Clearwater river, with its numerous gravel bars, is believed to have a considerable potential for the spawning of Salmon

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Figure 11 - Sediment Removed from the Coeur d'Alene River
at Cataldo, Idaho, is deposited in a Large
Lagoon.

and Steelhead which is of major importance to the commercial fishing industry. The innate clarity and attractiveness of the Clearwater together with the natural beauty of the surrounding areas make it a very valuable recreational resource.

PULP PRODUCTION

The timber resources of the river basins, as previously described, are very good for the manufacture of pulp, with possibility of utilization of much of the existing blight damaged, or dead wood, through building and operating a suitable number of wood pulping mills. The situation as regards location of the mills is not influenced as much by pulpwood supply areas west of the Continental Divide in Montana as in the Upper Missouri and Yellowstone river basins east of the Divide. The kinds of timber available are the same, consisting essentially of Douglas fir, Alpine fir, Spruce, Lodgepole pine, White bark and Limber pine, and Aspen.

Information furnished by the Northern Rocky Mountain Forest and Range Experiment Station, United States Department of Agriculture, indicate there has been only a very limited amount of pulpwood marketed from Western Montana and Northern Idaho. The potential supply from the allowable cut in the river basin described would amply take care of the needs of a number of pulp mills having 200 tons, or greater, daily pulp production capacity. It was pointed out there is enough dead timber available to keep several mills operating a long time 'without cutting a stick of green timber.'

There are four different kinds of wood pulp: mechanical pulp, sulfite pulp, sulfate pulp, and soda pulp. The first is prepared by purely mechanical means, the other three by chemical means. The mechanical pulp contains all of the wood except the bark and that lost during storage and transportation. Chemical pulps, however, are essentially pure cellulose, the unwanted and unstable lignin and the other noncellulosic components of the wood having been dissolved away by the treatment. Because of this, chemical pulps are much superior to mechanical, or ground-wood pulp, for fine papermaking. However, owing to the special processing required, they are too expensive for the cheaper grades of paper, such as newsprint.

For the purpose of this study of the mill sites, it was agreed to select a daily production capacity of 200 tons or more of pulp. The view expressed was that developments in the area under consideration would probably be confined to production of sulphate, or kraft pulp. Other methods of pulping were of interest, however, and it is possible that present views on the kind of pulp production will change. Interest was expressed in other wood pulping procedures, and ways and means for keeping pollutional wastes at a minimum.

As much of the potentially available pulpwood in western Montana and Northern Idaho is suitable for sulphate pulping, this preliminary study is limited to estimating the pollutional effects of sulphate pulp mill effluents on the streams. To aid in the general understanding of waste disposal problems associated with sulphate pulp mills, the following description of the process and manufacturing operations is presented.

SULPHATE (KRAFT) PROCESSDescription:

The sulphate process for making pulp and paper from wood is essentially a procedure for separating cellulose fibers from non-cellulosic substances in the wood. The process gets its name from one of the principal raw materials, sodium sulphate, referred to as salt cake. The term "kraft" is also applied to this process, derived from Swedish meaning strong. A more exact name, chemically speaking, would be the "Sulphide Process", since the sodium sulphate or salt cake must be reduced before use to sodium sulphide. While sulphate and kraft have been used synonymously, kraft has come to mean the high strength product now being manufactured at many mills, particularly in the South.

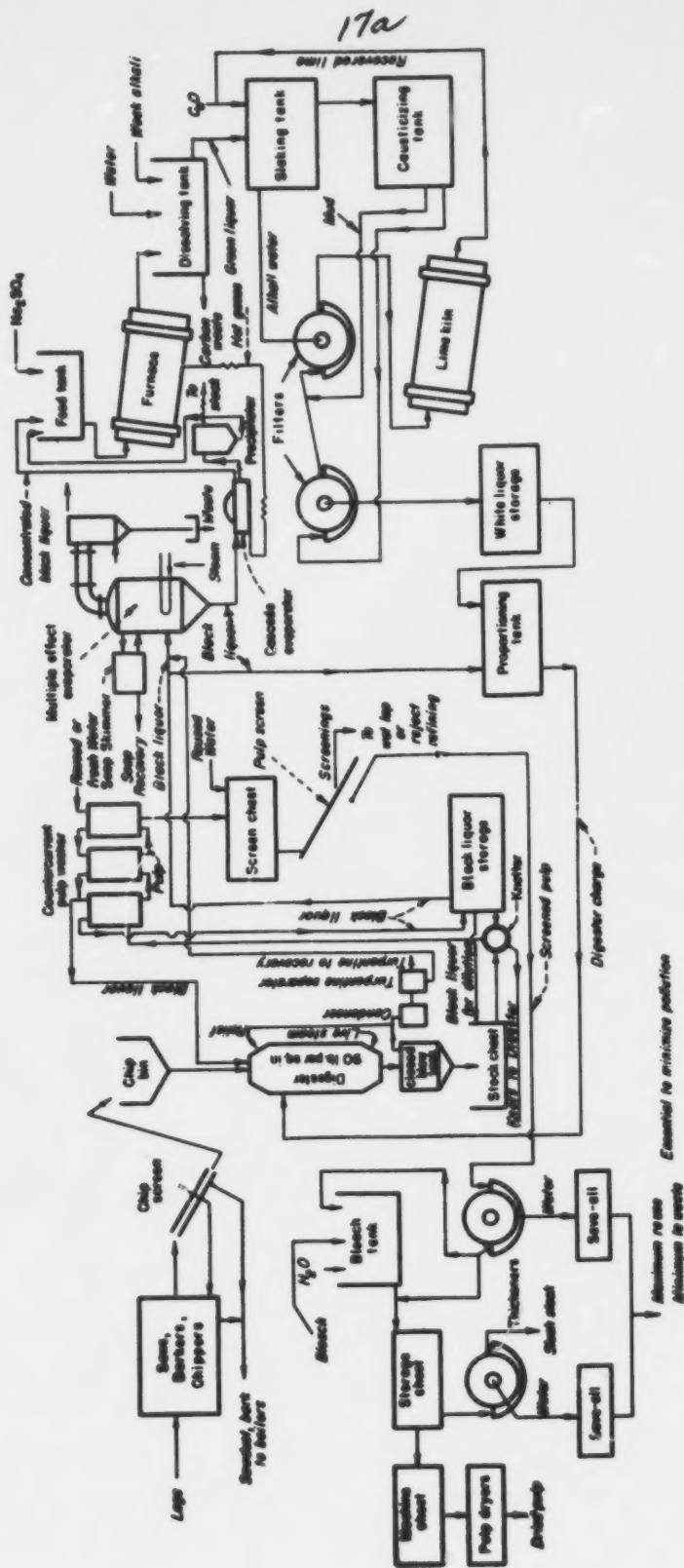
Initially, use of kraft pulp was confined mostly to coarse papers and board products. Uses for the pulp have been greatly extended. At present even dissolving pulp, containing over 95% alpha cellulose, is produced by the kraft process followed by bleaching treatment for the pulp. Modifications of the kraft process have made it possible to pulp hardwoods as well as pine and other coniferous woods. These developments have contributed to a remarkable growth of the kraft pulping industry in recent years.

Continuous improvements in equipment and procedure have followed the first use of the process. Chemical requirements for kraft pulping have greatly exceeded most other processes, and its application has always depended on recovery of chemicals and heat value of the lignin and other substances cooked from the wood. Advances during the past ten to fifteen years have brought recovery and utilization facilities available to a high degree of efficiency.

In a modern kraft pulp mill, most of the chemicals are recovered and processed for use again. Recovery values of 95% can be attained. Even dust formed while processing dry materials, and previously lost, is reclaimed by electrostatic methods. Fuel requirements have been reduced by better heat recovery. New equipment keeps pulp losses at a minimum. These developments to reduce waste, together with recovery of by-products, have resulted in more and better pulp with less use of materials.

The attached flow diagram for a kraft pulp mill, Figure 7 will be of assistance in connection with the following description of the kraft wood pulping process.

FLOW DIAGRAM FOR KRAFT PULP MILL



Wood Preparation: Pulpwood logs, sawed to suitable length, are conveyed mechanically to revolving barking drums where they are tumbled, rubbing against the sides of the drums and each other until the bark is removed. The bark falls through slots in the drums and is transported by conveyors to the boiler room, where it is burned to supply a part of the mill fuel requirements. The bark has no value in paper making.

Hydraulic barking of pulpwood has been employed in some mills, including some in the Northwest. The bark is removed from the logs by a jet of water operated under high pressure. The velocity of the water hitting the logs effectively strips away the bark and cleans the pulpwood. This requires large volumes of water and may occasion a disposal problem.

Logs with the bark removed are either sent to storage or to chippers. These chippers are heavy rotating discs equipped with steel knives that cut the logs into square chips usually ranging from $1/2"$ to $1"$ in size. These must be screened as chips over $1"$ may not be thoroughly cooked in the time they are in the digesters, and chips under $1/4"$ would be overcooked, resulting in a loss of wood. Slivers are removed. Rejects are sent to the boiler house for fuel. The chips are stored in round hopper bottomed tanks, called chip bins.

Digestion (Cooking) Process: From the chip bins, the chips are discharged into digesters, large cylindrical steel retorts in which the chips are acted on with suitable chemicals at elevated temperature to effect a separation of cellulose fibers. A digester is charged from the top with a given amount of wood chips, and the cooking liquor is added. The cooking liquor, called "white liquor", is composed of about $2/3$ sodium hydroxide and $1/3$ sodium sulphide in solution. Prior to adding any liquor to the digester, the white liquor is analyzed to determine the exact amount of hydroxide and sulphide, called "active alkali". The volume in gallons necessary to give a definite weight in pounds of active chemical is then carefully measured out in proportioning tanks. This volume of white liquor is supplemented with so-called "black liquor"; the liquor once used for cooking which has practically no active ingredients left but is utilized simply for additional liquid volume in filling the digester. Following these charging operations, requiring about twenty minutes, the cover of the digester is bolted tight and steam applied to start the cooking.

The total cooking time is about $2 3/4$ hours, with about $1 3/4$ to 2 hours being required to raise the temperature and pressure to the correct amounts: for example, 343°F. and 110 lbs. , respectively. The cooking is continued at full temperature for $3/4$ to 1 hour.

During this cook, the chemical reaction is essentially hydrolysis of lignin and carbohydrates, with the formation of compounds soluble in water.

or excess alkali. Sodium hydroxide is the solvent that acts on the wood chips. The sodium sulphide present does not act directly on the wood, but by decomposing it breaks down to liberate sodium hydroxide as the concentration of sodium hydroxide is reduced by use. Thus the sodium sulphide serves as a reserve supply of sodium hydroxide, making unnecessary a high enough concentration of the sodium hydroxide at any time during the cook to decrease the yield and weaken the pulp. This reaction of sodium sulphide explains the greater yield and stronger pulp produced by the kraft process as compared with the "Soda Process", which also uses sodium hydroxide as the chief solvent. The fats and resins in the wood are saponified, rendered soluble, and later separated and recovered. This recovery is important in reducing pollution, as will be discussed later. Cellulose fiber left free and in suspension, is the pulp.

Another step in the process of interest from the waste control point of view is turpentine recovery. In the steaming of the wood chips, the digester is vented to a condenser. The condensate is passed through a turpentine separator, and the reclaimed turpentine is drawn off to storage.

At the end of the cook, the digester is "blown", the term used for quick emptying of the pulp into a container called a "blow tank." The pressure is brought down to atmospheric, reducing the temperature to about 220°F. and stopping the digestion. The drop in temperature and pressure causes a large amount of low pressure steam to be formed. This steam can be condensed with a jet condenser to water having a temperature of 195° to 200°F., and used for washing pulp.

Pulp Washing: The contents of the blow tank resulting from the emptying of the digester are too thick to pump. It is necessary to dilute the pulp with black liquor from storage to about 4% fiber. The black liquor used is removed from the pulp in washing operations to be described. Automatic equipment is available to control dilution.

Knots may be removed either before or after pulp washing operations, and the knots and big chips that are not cooked are returned to the digester. From the knotters the pulp, referred to at this stage as "brown stock", diluted to about 1 1/2% fiber, is sent to the washers.

In modern mills, the earlier "diffuser" washing facilities have given way to more efficient counter current pulp washers utilizing three or four rotary vacuum filters. Each of these filters has a revolving drum, or cylinder, covered with a stainless steel wire cloth with about 40 meshes to the inch. The lower portion of the filter is under a vacuum and draws the liquor through the wire cloth leaving the pulp on the wire surface, the pulp being washed by showers as the drum slowly turns.

Pulp is washed on the first filter with filtrate from the second stage vacuum filter. The pulp leaving the first stage contains 11% to 15% fiber, which is diluted to about 1% by filtrate from the second stage, passes on to the second filter unit where it is washed with filtrate from the third stage, and again thickened to around 10% to 12% fiber. The process is repeated in the third and fourth stages, except that the final wash is with hot water, reused water generally employed in keeping water requirements and losses at a minimum.

From the last rotary filter in this counter current washing system, the clean stock is discharged to storage. While it is important that the stock be clean, it is also essential that the least possible amount of water be used since it must be evaporated in the chemical recovery cycle to be described.

The washed pulp is delivered at a "consistency" of about 4% fiber to the receiving operation, passing through a weight regulator and from there diluted with water to 1 1/4% consistency going to the screen units.

Pulp Screening: The pulp may be conveyed to ordinary flat screens, or discharged through a mixing pump to a flume flowing to centrifugal screens. The latter type of screen is equipped with fine screenplates against which the pulp flow is thrown by centrifugal force. The last of the uncooked chips and knots are removed. The tailings from the screens are removed and may be reclaimed either as wet lap stock on wet machines, or may be sent to a device which mechanically breaks the rejects up into fiber in the presence of hot liquor. The fiber and liquor are discharged to the blow tank, the process being called "reject refining."

The screened pulp is passed over a thickener to take out water and produce "deckered" stock of about 6% fiber. The pulp is delivered to storage, ready now to be pumped, diluted to suitable consistency with "whitewater", or reused water, to the pulp bleaching system, or direct to the machine chest and equipment for converting the pulp into the final product.

Chemical Recovery System: As previously pointed out, the chemicals used in the kraft process are recovered in large part and not permitted to go to waste. The flow from the counter current pulp washers containing most of the spent chemicals, called black liquor because of its dark color, is conveyed to a black liquor storage tank. The black liquor goes through a chemical recovery system, which may be briefly described as follows:

Essentially the procedure involves removal of water from the black liquor by evaporation, separation of organic and inorganic materials by burning out the organic substances, addition of salt cake make up at the furnace with its chemical reduction under temperatures maintained in the furnace and causticization of the soda with lime and with later recovery of the lime by burning to remove carbon dioxide in a lime kiln. Reference to the flow diagram, Figure 7, will be helpful in following the main steps in the chemical recovery cycle.

The weak black liquor is concentrated to a viscous solution of about 50% solids by steam heated, multiple effect evaporators, and subsequently evaporated further by being exposed to hot flue gases from the recovery furnace. This exposure to hot gases takes place in a cascade evaporator. In modern practice as many as six or seven evaporator units may be employed in multiple effect evaporation to make the least amount of steam remove the maximum amount of water from the black liquor.

A weighed amount of salt cake is added to the concentrated black liquor before being sprayed into the furnace. There is enough organic matter in the solids to burn and evaporate water left in the black liquor, with enough heat to spare for generation of steam in a boiler located over the furnace. In the furnace a reducing atmosphere is maintained to convert the sodium sulphate to sodium sulphide by the reaction $\text{Na}_2\text{SO}_4 \xrightarrow[\text{Heat}]{2\text{C}} \text{Na}_2\text{S} + 2\text{CO}_2$. This reaction requires heat in addition to that required for evaporation of the remaining water in the black liquor, but there is still sufficient for production of steam needed in the process.

A molten smelt is discharged from the furnace which looks like molten slag, or iron issuing from an iron blast furnace. This smelt is essentially sodium carbonate and sodium sulphide. It is dissolved in weak wash liquor from the causticizing operations, or reused water from other sources, until a total alkali concentration in the dissolving tank of about 1 pound of sodium oxide (Na_2O) per gallon is produced. The resulting solution is known as "green liquor". When the proper concentration is reached, it is ready for use in the causticizing step in the chemical recovery cycle.

Hot flue gases after passage from the furnace through the cascade evaporator still contain considerable fine dust. In earlier days the practice was to discharge this to the atmosphere. Modern mills usually are provided with electric precipitators designed to remove more than 90% of the fine dust, or smoke particles, which are essentially very fine particles of sodium sulphate. These are given an electrical charge and in passing through an electrical grid, the particles are attracted to rods

having an opposite charge. The smoke particles deposited on the rods are removed and mechanically returned to the chemical recovery system.

Causticizing: Green liquor is received while hot from the recovery system and clarified. Dregs removed are thickened, washed, and discarded. Clarified green liquor is discharged to storage, then heated to near boiling in connection with the next operation, which is treatment with lime for causticizing. The green liquor and lime are proportioned into the slaking tank, with conversion of sodium carbonate to sodium hydroxide of about 60%, the reaction being $\text{Na}_2\text{CO}_3 \nearrow \text{CaO} \nearrow \text{H}_2\text{O} = 2\text{NaOH} \nearrow \text{CaCO}_3$. Commercial lime is used, containing some rock, so it is necessary to remove the rock and grit by a classifying unit. The material removed is washed and discarded. The causticized green liquor requires time for completion of the above reaction, usually carried out with mechanical agitation or stirring. The time of contact under agitation is important, since the longer the time the higher the conversion of carbonate to caustic can be carried and with less excess of lime. The usual time is 1 1/2 to 2 hours. The fully causticized green liquor still containing the lime sludge is called "white liquor".

The white liquor must be freed of the lime sludge. This can be accomplished with a sludge filter, or by suitable clarifiers. The clarified liquor is discharged to white liquor storage to be used again in the pulping process previously described.

The lime sludge is then diluted with filtrate from the sludge filters, and sent to a sludge washing system. The counter current principle is again used. The clean, washed and thickened sludge, 56% to 58% solids, is conveyed to a lime kiln for calcining.

Lime Recovery: This step in the operation is essentially to convert the lime to a suitable condition for reuse. Sludge from the filters is conveyed to a gas or oil fired lime kiln, and it is subjected to increasing temperatures as it passes toward the firing end. The sludge is completely dried, and then gradually heated until the temperature exceeds 1610° F. when it is calcined to quick lime, following the reaction $\text{CaCO}_3 \nearrow \text{Heat} \nearrow \text{CaO} \nearrow \text{CO}_2$. This reaction proceeds faster as the temperature approaches 2000°F. The quick lime is then ready for further use in treating green liquor in the slaking tank.

Dust that might cause atmospheric pollution if discharged with the lime kiln flue gas can be controlled by passing through a water scrubber, trapped, and returned to the kiln.

KRAFT PULPING WASTES

The waste effluents from the kraft pulping process described carry materials the amounts of which depend upon equipment provided to reduce losses and efficiency of individual plant operation. About half of the pulp wood used is dissolved in the cooking liquor leaving a residue of cellulose fibers as pulp. Spent liquors contain the lignin, hemicellulose and sugars from the wood along with chemicals and a small amount of fiber lost in the washing and dewatering operations. Most of the dissolved materials are concentrated and burned for their fuel value in the chemical recovery system.

In modern kraft mills the procedure in handling wastes consists essentially of burning the bark from the pulp wood, burning or recocking the knots, reprocessing or marketing the rejects and screenings, recovering and selling of turpentine and tall oil, reclaiming of lime sludge from the causticizing operation, recovering the fiber for including in the product, along with the reclaiming of the heat values of dissolved substances in the spent cooking liquor and chemicals utilized in the process.

Chemical recovery has reached a high state of efficiency. Operating results at modern mills have shown 95% recovery, one new mill reporting only 70 pounds of salt cake as the required make up for chemicals lost per ton of pulp produced. This mill is fully equipped to keep both stock and sewer losses at a minimum.

Wastes that remain for disposal include lime slaker grits and dregs from the causticizing step in preparation of the cooking liquor. These insoluble inorganic materials are usually disposed of in lagoons, or are dewatered and disposed of as fill near the mill.

The process waste water or effluent that needs to be disposed of from a kraft mill will usually range between 20,000 and 40,000 gallons per ton. This is made up of those waters not reused in the process, and which contain varying amounts of spent chemicals and wood substances not reclaimed in the steps previously described. Such an effluent is either discharged directly from the mill, or is lagooned for controlled release, or is given suitable treatment prior to entering a stream or other waters.

The major effect of the effluent on the receiving waters is removal of dissolved oxygen. If the oxygen is depleted sufficiently fish will suffocate, or migrate and other objectionable conditions will occur. It is necessary, therefore, to keep oxygen requirements of the wastes as discharged to a stream at a sufficiently low value to prevent serious oxygen depletion.

The oxygen demand of a waste may be expressed in pounds required per unit of product, such as pounds of B.O.D. per ton of kraft pulp. This may be compared with the oxygen requirement of domestic sewage by dividing the pounds of B.O.D. of the wastes per ton by the amount of oxygen required per person to oxidize sewage, giving the "population equivalent" of the wastes. The population equivalent on the basis for each ton of kraft pulp produced would range from 250 to 400, the latter figure being used in the studies to be described. Since a modern mill should be able to keep the population equivalent below 300, a factor of safety has been introduced to take care of any unusual operating condition.

Other considerations involve reduction of constituents responsible for imparting color, taste and odor to waters used for public water supply. It is essential to keep certain substances such as mercaptans, resin acids, and sulfides in the condensates, turpentine decanter and floor washings below the amounts that are toxic to fish and aquatic life needed as fish food. A modern development to reduce toxic materials has been to use stripping towers for the condensates, utilizing stack gases from the power plant.

The principal waste from the pulping process is the overflow from the decker seal pit, which contains those chemicals and wood constituents that were not removed in the pulp washing. It varies in strength from 200 to 500 ppm of B.O.D. The greatest step in improving this part of the process has been the development of counter current vacuum washing systems that have practically removed such washings from the mill effluent. Chemical recovery was increased and the B.O.D. of the effluent was reduced at least 50% as compared with the earlier method of diffuser washing. Counter current vacuum washing systems are being installed in new kraft mills.

The other discharges from the pulping operations include log wash water, digester relief and blow down condensates, turpentine decanter water and floor washings. These are generally lower in volume and strength (B.O.D.) as compared with the overflow from the decker seal pit.

The chief waste from the chemical recovery system is the condensate from the evaporators. Use of barometric condensers produces an effluent low in oxygen demand but high in volume, while use of a surface condenser gives a low volume of waste water relatively high in B.O.D. Employment of long tube evaporators, utilizing up to seven effects, reduces the entrainment loss, or carry-over, responsible for high losses previously experienced in this operation. The development of better foam control and trapping devices has helped materially to minimize black liquor carry-over into the condensate.

Usually facilities are now provided along with the black liquor evaporators to remove the 'sulphate soap' and tall oil, with the liquor from the soap skimmer being conveyed on to the last stage of the multiple-effect evaporators. The soap may be sold to refiners. There is a market for tall oil. If not reclaimed, the skimmings need to be sent to the cascade evaporator and recovery furnace for concentration and burning to minimize components in the mill effluent that in sufficient concentrations may be toxic to fish and aquatic life.

Lime sludge is dewatered and calcined for reuse, or may be lagooned and utilized as agricultural lime. The remaining waste waters from the chemical recovery section of a mill are small in volume and low in strength as regards pollution.

OTHER PULPING PROCESSES AND EFFLUENTS

It will be understood from the foregoing discussion that the waste effluents from pulp mill operation carry materials which vary with the process used and with the efficiency of individual plant operation. In the other principal chemical pulping processes, sulfite and soda, more than half of the wood used is dissolved in the cooking liquor leaving a residue of cellulose fibers as pulp. The spent liquors contain lignin, hemicellulose, and sugars in solution and a small amount of fiber in suspensions which is lost in the washing and dewatering operations.

Sulfite waste liquor (calcium base process) is usually discharged into adjacent waterways without further treatment. After extensive investigations on a pilot-plant scale by three different companies, the first commercial installation of a new recovery process for the chemicals and organic matter normally discharged as waste was made at Longview, Washington.

In this modified sulfite process magnesium oxide is used in place of the lime which customarily has been employed as the base for the cooking liquor. The process is generally referred to as the magnesium base sulfite process. Because of the necessity to recover in excess of 95 percent of the magnesium oxide for economical operation, the waste liquor is removed as completely as possible from the pulp by counter-current vacuum washers. The washings as well as the waste liquor drained from the pulp are evaporated to about 60 percent total solids and burned in a waste liquor recovery boiler.

In addition to the recovery of the magnesium oxide, most of the sulphur and the fuel value of the organic solids, are recovered. The

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waste heat boiler supplies the steam required for cooking, evaporation of the liquor, and other requirements of the pulp mill in addition to supplying as a by-product much of the electric power needed in the plant.

An attractive feature of this process particularly in locations where fuel is scarce and its cost high, is the utilization of the fuel value of these waste liquors to supply the normal steam and power requirements of the pulp mill. This new process now fairly well proven on a commercial scale reduces the necessity for other means of disposal of the liquor. With good operation of such a pulp mill, studies indicate there would be much less effect on the waters into which any effluent of the mill would be discharged than with the calcium base sulfite process.

The same advantage from the point of view of water pollution reduction over the usual sulfite pulping method applies to the ammonia base process. The plan of operation is essentially as described above except the ammonia is lost up the stack in present mills in burning the organic material removed from the pulpwood.

The so-called semi-chemical process for pulping wood is particularly suitable for use of hardwoods. From the waste utilization point of view it is desirable when this process is utilized to operate it along with a kraft pulp mill.

Since the groundwood pulping process employs only a mechanical grinding of wood, the effluent from this process carries in solution only a very small amount of water-soluble material extracted from the wood. Also carried in suspension is a small amount of fine wood fibers which pass through the wire screens used in dewatering the pulp.

Pulp bleaching as a step toward production of high grade pulp and paper products is simply indicated on the flow diagram, Figure 7, without going into the various steps employed in a modern bleaching system. In the study of mill sites in Montana and Idaho, the basis of comparison in determining the relative suitability of proposed locations as regards effluent disposal, no attempt has been made to go into a detailed account of effects of converting the pulp into paper products.

To provide some understanding of the procedures employed and waste ingredients, the following brief outline of paper manufacture is presented:

PAPER PRODUCTION EFFLUENTS

In the paper-making process, the sheet is formed by filtering the fibers from a water suspension on a fine-mesh wire screen. In the formation of the paper sheet, the water passing through the screen (white water) carries a considerable quantity of fiber. In order to avoid large losses of fiber, this white water is recirculated through the system. In other words, instead of adding fresh water for washing and dilution of pulp stock, the white water is added for this purpose. However, it usually results that there is a surplus of white water over that needed for make-up and the unused portion, after passing through filters or settling tanks, is discharged into the mill effluent. In addition to the cellulose fibers, white water effluent from paper mills may contain some clay or other mineral fillers, sluz, rosen-size, and dye used in the manufacture of various kinds of paper. The quantities of suspended solids in the effluent from both pulp and paper mills may vary considerably among individual mills. This is a result of the different products being manufactured, the process used, type of equipment available, and method of operation.

The so-called 'white water' wastes, applied to the fiber and other paper making materials in suspension, are kept at a minimum by recirculation. Save-all equipment is employed to remove the paper making solids in the white water before discharge from mills. There is usually some type of filtering or clarifying device designed to return the reclaimed material to the pulp and paper-making process. Utilizing more recent equipment, the losses of fiber can reasonably be kept below a half pound per thousand gallons of effluent.

SUMMARY ON WASTES

The present procedure in pulp and paper mills is to reduce wastes at their source, reclaiming as much of processing chemicals and wastes as practical, returning these materials to the system for pulp and paper manufacture. An increasing number of by-products have been developed from wastes. Reduction in mill losses have brought about very substantial decreases in pollution caused by effluents.

Recycling of process waters has done much to reduce volume of effluents. As indicated, the usual volume per ton of kraft pulp in modern mill practice range from 20,000 to 40,000 gallons. The strengths of the wastes should definitely be kept under a population equivalent of 400 per ton. With careful operation the strengths should be substantially less than this number.

There is a trend toward monitoring of effluents, using automatic control equipment to reveal increases in strengths of wastes due to leaks, spills and other unusual or emergency conditions arising in mill operation. Diversion of wastes at these times to lagoons, or other suitable means, have been utilized to avoid "slugs" of pollution. It is very important to make provision for avoiding such difficulties in the design and construction of new mills.

Summarizing briefly kraft mill waste disposal procedures, consideration should be given to the following items:

1. Dry bark and waste wood -- should be utilized or burned, ashes to be kept out of streams.
2. Screen rejects -- reclaimed or burned.
3. Grit and dregs from lime slaker -- disposed of on dump, or utilized for fill, surfacing material, etc.
4. Tall oil and soap -- to be removed and either marketed or incinerated.
5. Fly ash -- to be disposed of other than discharged to stream.
6. Fibers in white water -- to be kept at minimum by efficient saveall system.
7. Chemicals dissolved in effluent -- loss to be kept at minimum with modern reclaiming equipment, including countercurrent vacuum filter washing of pulp. Consider waste monitoring and control equipment and lagooning for wastes.
8. Lime sludge -- recovery and reuse, or disposal for agricultural lime.
9. Sanitary sewage -- treated and disposed of in a sanitary manner.
10. Refuse -- incinerated or disposed of in such manner as to be kept out of streams.

Such considerations have entered into the estimates of effects of mill wastes on streams at sites previously described. Other factors involved are discussed in the following sections:

FACTORS IN THE STUDY

Generally the most important effect of pulp and paper mill effluents on aquatic life is considered to be the removal of oxygen from the water into which the effluent is discharged. If the volume of water receiving the effluent is not large enough, or its oxygen content is low the oxygen depletion may result in reduction of the dissolved oxygen to a level below that necessary to sustain fish life. The dissolved oxygen tends to be gradually restored by natural aeration. The Pollution Control Council, Pacific Northwest Area, has recommended a minimum of six parts per million of dissolved oxygen as a water quality objective for waters used for the growth and propagation of fish, shellfish and other aquatic life. Pulp and paper mill wastes may also have toxic effects on the fish and fish food organisms in a stream if dilution is inadequate. This may be the limiting factor in streams having relatively high dissolved oxygen resources.

Stream Data:

This study did not include a detailed field survey of the streams for the collection of specific analytical data indicating the present sanitary, biological, physical, and chemical condition of the waters. Data utilized in this study were limited to those which were available from existing records of various governmental and private agencies. Stream temperature data were obtained from the Montana Power Company and U. S. Geological Survey records. Stream flow data were obtained from the U. S. Geological Survey. Information on the relative importance of fishery resources and extent of other uses of the streams was obtained from both publications and inquiry of persons familiar with them.

Data on the types and quantity of wastes presently being discharged to the streams were obtained from the Inventory of Municipal and Industrial Waste Facilities in the area involved. This inventory was cooperatively developed by the States and the Public Health Service.

It was necessary to estimate the present dissolved oxygen concentration and biochemical oxygen demand of the stream waters from knowledge of the characteristics of the streams, pollution known to be entering, and related information obtained from the Montana and Idaho State Departments of Health.

Water Quality Objectives:

The effect of kraft pulp mill wastes on existing and possible future installations of drinking water supplies is the introduction of color, taste and odors. The probable extent of such effects was considered. The effect on industrial water supplies would generally not be appreciable although the wastes may make some sections of the rivers less suitable for a few industries with special process water quality requirements. Available information indicates there are no such industries presently taking water from sections of the streams under consideration.

Kraft pulp mill wastes may add some color, odors and possibly cause some foaming in the stream below the mill waste outlets. Under certain conditions some wood fiber may be deposited on the bottom of quiescent areas of the stream, some of which may later rise to the surface. The high fiber recovery efficiency attainable in modern mills will minimize this possibility. The probable extent of such effects on the esthetic quality of the waters at each site is described.

Based on information obtained, it is assumed that all sectors of the streams under consideration are suitable habitat for, and contain substantial cold water fish populations and may contribute to the propagation of salmon which is essential to the maintenance of a major segment of the Pacific Northwest Fisheries Industry. Maintenance of over-all stream conditions suitable for propagation of such fish population is considered an essential requirement to be met at any pulp mill site selected. The dissolved oxygen (D.O.) criterion used in the analysis is that a minimum of 6 ppm of D.O., as recommended by the Pacific Northwest Pollution Control Council, be maintained in the stream at the most critical conditions expected to occur once in ten years.

Certain constituents in kraft pulp mill wastes are toxic to fish and other aquatic organisms when present in sufficient concentration in the stream. Dimick and associates (3) have demonstrated that the effluent from three different kraft mills when diluted 1:20 did not kill silver salmon under laboratory conditions.

The data obtained in a biological study (3) of one Pacific Northwest stream consisting of investigations before and after the beginning of operation of a kraft mill give some indication of the toxic effects of kraft pulp mill wastes on the suitability of a stream for propagation of salmon and steelhead trout. The pulp mill wastes were discharged in such a manner that apparently the wastes were distributed in only one-half of the width of the stream in the sector studied. Assuming that this half was effectively utilized for uniform disposal of wastes in the water, the dilutions in this situation would be in the ratio of 1 to 50. The affected area of the stream was unsatisfactory for some desirable fish food organisms and unfit as a spawning area for fish. It extended a distance of 2.2 miles below the mill outlets where the streams joined a larger river and observable biological effects disappeared.

From the above information and additional fish toxicity data reported by Van Korn, Anderson, and Katz (4), and Cole (5), the following basis was selected for evaluating such toxic effects pulp mill wastes might have on aquatic life at sites considered:

Fish will not be killed in dilutions of mill wastes to stream flow of 1 to 50 where conditions are otherwise suitable for fish. At dilution of 1 to 75 or above, there will be negligible, if any, detrimental toxic effects on fish food organisms, spawning areas,

or other factors of the stream environment that may indirectly reduce existing fish populations.

Inasmuch as irrigation is a significant use of the waters of all of the streams, the effect of the pulp mill wastes on the suitability of the waters for this purpose is an important consideration. There appears to be relatively little specific information on the effects of pulp mill wastes on irrigated crops or on the soil. One kraft mill is currently conducting a study of the suitability of combined mill effluent for crop irrigation which may provide this needed information. There are no known instances of detrimental effects of kraft pulp mill wastes on irrigated crops. With dilution of pulp mill waste by flow in the ratio of 1 to 50, the total increase of the sodium cation on the stream will be less than 2 ppm. The total increase in sulfides will be less than 0.2 ppm. The above concentrations are considerably below those found in waters considered excellent for irrigation (6). The concentration of other cations, anions, and organic materials resulting in the stream from the pulp mill wastes should not have a significant effect on the suitability of the water for irrigation. Inasmuch as at normal flows the dilution ratio will be greater than 1 to 50, it is improbable that the pulp mill wastes will have any detrimental effect on irrigated crops.

Methods of Analysis:

It was assumed that the minimum size of the kraft pulp mill which might be established west of the Continental Divide in Montana or the northern portion of Idaho would be 200 tons of pulp per day capacity. Stream flow records of all the streams in the Clearwater, Koontenai, Pend Oreille, and the Spokane River basin in this area were investigated to the extent necessary to eliminate those streams or sectors of streams which apparently could not assimilate the wastes from a 200 ton pulp mill without detrimental pollution effects. An estimate was made of the probable pollution effects of the wastes from a pulp mill in all sectors of streams which might possibly assimilate the wastes without undue detrimental effects on other desirable uses of the waters.

A population equivalent of 400 per ton of pulp produced (representing the biochemical oxygen demand of the waste) was used in these estimates. A waste flow of 40,000 gallons per ton of pulp was assumed. This is based on the results of numerous determinations of the biochemical oxygen demand (B.O.D.) and volumes of wastes discharged in studies made of a considerable number of kraft pulp mills, obtained from records of the Wisconsin Committee on Water Pollution and others. This represents operating data of plants constructed prior to World War II. Recent studies show a modern mill can be operated with significantly less waste discharged, so the use of the above value introduces a factor of safety into the calculation.

It was assumed that waste outlets into the stream will be located and otherwise designed to accomplish rapid mixing of the wastes with the total flow of the stream. It is also expected that suitable precautions will be taken to prevent the discharge of slugs of waste into the stream as the result of spills or for any other reason. In addition to the above it is expected that the mill will be designed and operated in a manner such that the water polluting wastes discharged will be reduced to the practical minimum. Treatment, per se, of the wastes has not been assumed in these estimates.

The minimum stream flows which would be expected to occur within various periods of time were estimated by a method developed and used by the U. S. Geological Survey. The estimated 10-year minimum daily summer and winter flows for the various sectors of the streams considered are shown in Table 1. These were selected as the critical flows on which other estimates are based.

The minimum or critical values of dissolved oxygen below the proposed sites were calculated using the oxygen sag curve formula developed by Streeter and Phelps as modified by Fair (8). The value of the self-purification constant selected for each site was on the conservative side of the ranges suggested by Fair for streams of similar flow characteristics. Reduced values were used for winter conditions to compensate for possible effects of ice coverage.

The B.O.D. loading used in the computations for each stream sector included the following:

1. An assumed B.O.D. of the stream as it enters the sector. The value of 1.5 ppm ult. @ 20° C (approximately 1.0 ppm 5 day B.O.D. @ 20° C) was selected for sectors believed unaffected by upstream organic waste discharges. The value was increased if it appeared that significant upstream B.O.D. loadings were not essentially stabilized when entering the sector.
2. The B.O.D. of significant quantities of the known municipal and industrial wastes discharged in the sector.
3. The B.O.D. of the wastes discharged by the pulp mill.

The estimated B.O.D. loading in each sector of the stream is shown in Table 2.

Saturated conditions of dissolved oxygen in the stream above each sector was assumed. The dissolved oxygen values are also shown in Table 2.

Stream Flow Studies

The Clark Fork and Pend Oreille Rivers

Stream flow records of these two rivers investigated in some detail was limited to the main stem of the Clark Fork below the junction with the Blackfoot River above Missoula to Pend Oreille Lake and the main stem of the Pend Oreille. Preliminary review of stream flows indicated that other sectors and tributaries exclusive of the Flathead River had insufficient flows to assimilate the wastes from a 200 ton kraft pulp mill.

The Clark Fork River below the junction with the Blackfoot River and above the junction with the Bitterroot River near Missoula is a fast-flowing stream with good reeration characteristics. Its maximum temperature is reported to range from 71-73° F. There is some regulation of flow by the power plant at Bonner and there are diversions upstream for irrigation. Minimum summer flows have almost always occurred in September and minimum cold weather flows have most frequently occurred in January and December. The estimated 10 year minimum daily flow in the winter (November to March) is 350 second-feet and in the summer (May to September) is 430 second-feet.

The Clark Fork from Missoula to St. Regis is also a fast flowing stream with good reeration characteristics. It reaches a maximum temperature of about 72° F. Flows are affected to some extent by regulation at the power plant at Bonner and upstream diversion for irrigation. Based on records of the U.S.G.S. gaging station below Missoula the estimated 10 year minimum daily winter flow is 700 second-feet and in the summer is 740 second-feet. The low flows occur during the same periods of the year as they do above Missoula.

The estimate of minimum flows in the sector of the Clark Fork from St. Regis to the junction with the Flathead River is based on records of the U.S.G.S. gaging station at St. Regis which is located just one-half mile below the junction with the St. Regis River. The estimated minimum 10 year daily winter flow is 1140 second-feet and for the summer is 1340 second-feet. It is relatively fast moving in all portions of the sector.

Except for a limited distance upstream from the power plant at Thompson Falls and Albion Falls the Clark Fork is a relatively fast flowing stream in all portions of the sector extending from its junction with the Flathead above Plains to the point of discharge into Pend Oreille Lake. The estimate of minimum flows in this sector is based on records of the U.S.G.S. gaging station above Plains and below the junction with the Flathead. The calculated 10 year minimum daily winter flow is 3600 second-feet and 10 year minimum daily summer flow is 4500 second-feet. A more limited examination of the records of the gaging station near Heron indicate that the flow is somewhat greater in that vicinity. There is some diurnal fluctuation below the Falls and it is assumed that there will be similar effects below Albion Falls. Maximum temperature is expected to be in the vicinity of 72° F.

The estimate of minimum flows in the Pend Oreille below Pend Oreille Lake is based on records of the U.S.G.S. gaging station below Z Canyon, near Meteline Falls, Washington. Flow in this sector is affected by natural storage in Pend Oreille Lake and the ~~Alsea~~ ^{Alsea} Falls dam near the Idaho-Washington boundary. The estimated 10 year minimum daily winter flow is 3800 second-feet and in the summer is 6700 second-feet. It may be noted that the minimum winter flows are comparable with those for upstream at Plains, Montana although low summer flows are appreciably higher at Z Canyon. It is assumed that the critical low flows are very nearly the same throughout all of this sector. Flow is moderately fast in the Pend Oreille River and it is reasonable to assume that it has good reseration characteristics. U.S.G.S. records show that the maximum temperature reached in 1949 was 71° F.

Flathead River

The Flathead River is a rapid-flowing stream with numerous sectors of turbulent flow. It can be assumed that it has excellent reseration characteristics in all sectors with the one exception of Flathead Lake. It is a relatively cold stream. Temperature data collected by the U.S.G.S. showed that the maximum temperature reached in 1939 was 68° F. on August 3 and 4.

The estimate of minimum stream flows for the sector above the junction with the South Fork is based on records of the U.S.G.S. gaging station located 10 miles northeast of Columbia Falls. The calculated 10 year minimum daily winter flow is 350 second-feet and for the summer period is 570 second-feet. There is no diversion or regulation of flow above this station.

The estimated minimum flows in the sector extending from the junction with the South Fork to Flathead Lake is based on records of the U.S.G.S. gaging station at Columbia Falls. The estimated minimum winter daily flow in this sector is 860 second-feet and the minimum summer flow is 1540 second-feet. The construction of Hungry Horse Dam will affect the minimum flows which occur in the future.

The estimate of minimum flows in the sector extending from Flathead Lake to the junction with the Clark Fork River is based on records of the U.S.G.S. gaging station near Polson which is located one-half mile downstream from Kerr Dam. Flows in this sector are regulated to some extent by Flathead Lake. The estimated 10 year minimum daily winter flow is 1400 second-feet and the summer period is 2,050 second-feet.

Kootenai River

The Kootenai River in the United States is a fast-flowing stream with frequent sectors of turbulent flow throughout its length. It is a relatively cold stream. Temperature data collected by the U.S.G.S. show that the maximum temperature reached in 1949 at Port Hill, Idaho was 69° F. It is assumed that the maximum temperature reached in upstream sectors will not be greater and probably will be somewhat lower than the temperature at Port Hill.

The estimated minimum flows of the sector from Newgate, British Columbia to Libby, Montana is based on records of the International Gaging Station at Newgate. At the present time there is no diversion or regulation affecting flows in this sector. It has been unofficially reported that Canada has been considering the possibility of some major upstream diversions which would affect future flows in this sector. The estimated 10 year minimum daily winter flow is 1150 second-feet. The minimum summer flows are much greater as indicated by the estimated 10 year minimum daily summer flow of 3770 second-feet.

The estimated minimum flows in the sector extending from Libby to Bonners Ferry is based on records of the U.S.G.S. gaging station at Libby, Montana. At present there is no known diversion or regulation of flows in or above this sector. Flows would, of course, be affected by any significant diversion that may be established in Canada. The estimated minimum 10 year winter daily flow is 1310 second-feet and for the summer is 3800 second-feet.

The estimated minimum flows in the sector from Bonners Ferry to Port Hill, Idaho is based on records of the U.S.G.S. gaging station at Bonners Ferry. The calculated minimum daily winter flow is 1450 second-feet and for the summer is 4480 second-feet. The minimum daily flows were also estimated from records of the International Gaging Station at Port Hill, Idaho. Minimum flows at this location are comparable to those at Bonners Ferry, the 10 year minimum daily winter flow being 1500 second-feet and the summer flow 4300 second-feet.

Spokane River

The estimated minimum flows of that portion of the Spokane River extending from Coeur d'Alene Lake to the Idaho border is based on records of the U.S.G.S. gaging station near Post Falls, Idaho. The calculated 10 year minimum daily winter flow is 480 second-feet and for the summer is 140 second-feet. These are extremely low flows for a river of this size. They are principally due to the great amount of diversion from the stream for irrigation purposes. The minimum summer flows usually occur in August and September and the flow is normally very low throughout the entire month of September. No temperature data was available for the Spokane River. It was assumed that its maximum temperature would not exceed 72° F. which is true of other streams in this area for which temperature data are available.

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Figure 12 - Clearwater River in Idaho: Near Junction
of the North and South Forks.

Clearwater River

The Clearwater River is very appropriately named. In an area of the country where there are many clear and sparkling streams the Clearwater is outstanding in these characteristics. It is a fast-flowing stream, with many portions of turbulent flow, and its reeration characteristics are undoubtedly very good. The limited temperature data available indicates that its maximum temperature probably does not exceed 72° F.

The estimated minimum flows of the sector from Kamiah, Idaho to Spaulding, Idaho are based on stream flow records of the gaging station at Kamiah. The calculated minimum 10 year daily winter flow is 480 second-feet and for the summer is 780 second-feet. There is some diurnal fluctuation due to a power plant on the South Fork.

Estimated minimum flows in the sector from Spaulding to Lewiston are based on the records of the U.S.G.S. gaging station at Spaulding. The calculated minimum daily winter flow is 1,000 second-feet and for the summer is 1600 second-feet.

SUITABILITY OF SECTORS OF STREAMS TO ABSORB PULP MILL WASTES

Clark Fork above Missoula between the junctions with the Blackfoot and Bitterroot Rivers

Significant quantities of oxygen consuming organic wastes are discharged into the headwaters of the Clark Fork. Such discharges are sufficiently distant upstream from the junction of the Blackfoot and the Clark Fork above Missoula so that they are expected to be essentially stabilized by the time they reach the sector except possibly during the winter periods when stabilization proceeds more slowly. It is not believed that they would have significant effect on the oxygen resources of the Clark Fork River below the junction with the Blackfoot. Although this sector has relatively low minimum flows the calculated critical dissolved oxygen concentration which would occur downstream as the result of discharge of wastes from a 200 ton kraft pulp mill is 5.4 ppm. This D.O. would occur in the warm weather period. The minimum D.O. concentration which would result during the winter period was calculated to be 11 ppm.

At the minimum 10 year daily flow of 350 second-feet the dilution ratio of wastes from a 200 ton pulp mill in the stream would be 1-28. With this limited dilution available it is expected that the toxic effects of the wastes will reduce the quantity of desirable fish food organisms present and impair any existing fish-spawning areas in the sector of the stream from the mill waste outlets to the junction with the Bitterroot River. This would tend to reduce the total fish population in the vicinity. Noticeable odor, color and foam in the stream from the mill wastes would result in a sector of the stream below the mill.

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Figure 13 - Lumbering constitutes the Major Industry in the
Clearwater River Valley Above Lewiston, Idaho.

It appears that there are not any municipal water works presently obtaining water from the Clark Fork. It is expected that any drinking water supplies which might be taken in the future from the stream within 50 miles below the discharge of wastes from a 200 ton pulp mill might have tastes and odors which would be more severe during winter periods. The stream would probably be useable as a source of municipal water supplies but there would be increased costs involved because of the additional treatment which would be required.

It is not expected that the pulp mill wastes would have any significant effect on downstream use of Clark Fork River water for irrigation purposes.

Analysis of the available information and data indicates that the principal serious pollutional problem which would result from discharge of wastes from a 200 ton kraft mill in this sector of the stream would be toxic effects on the aquatic life in the stream. It is expected that there would be appreciable reductions in the quantity of desirable fish food organisms. Any existing fish spawning areas would also be adversely affected. In order to prevent such detrimental effects a 200 ton kraft mill would necessarily have to reduce the quantity of wastes discharged below that which is normally accomplished by these mills and would have to take extreme precautions to assure that there would be no spills or slugs of wastes which would reach the stream. Some additional treatment of the wastes might also be required.

It is believed that construction of a mill in this vicinity should not be considered unless there are other factors favoring this site which would justify above normal waste control measures by the mill.

Clark Fork River from Missoula to St. Regis

From the information available it is estimated that the population equivalent of organic wastes discharged throughout the year into the Clark Fork into the vicinity of Missoula is about 21,000. During the period in the fall and winter when the beet sugar plant is operating, it is estimated that organic wastes having a population equivalent of 115,000 is discharged. Assuming that a 200 ton kraft pulp mill were to discharge wastes into the sector, the calculated minimum dissolved oxygen concentration which would be expected at the minimum daily 10 year summer flow would be 6.1 ppm. The calculations indicate that the minimum D.O. would not fall below 8.1 ppm in the fall when the beet sugar plant is operating. Dissolved oxygen concentrations during minimum flows in the winter are not expected to drop below 10.6 ppm. At the estimated 10 year winter flow of 707 feet the dilution ratio of mill waste to stream

flow is 1-57. At this dilution it is possible that there will be some reduction of desirable fish food and organisms and impairment of fish-spawning areas for some distance below the mill waste outfall. This may tend to reduce the number of fish in the sector to some extent, but it is doubtful that it would have a significant effect.

There will be some impairment of the suitability of the Clark Fork as a source for drinking water supplies. As far as is known, waters of the Clark Fork are not presently utilized as a source of drinking water.

The esthetic quality of the stream a short distance below the mill waste outlet may be impaired somewhat due to foaming, odors and color from the wastes. It is believed that the sector in which such effects are noticeable will be relatively limited. It is not expected that there will be any appreciable effect on the quality of water for irrigation purposes.

It appears from the analysis of the available information and data that a 200 ton kraft pulp mill could be established in this sector without creating material pollution of the stream. There may be some effect on the fish populations but these are expected to be very limited. Reduction of the waste load presently discharged in this sector may be necessary and should be investigated.

Clark Fork from St. Regis to its junction with the Flathead

The establishment of a 300 ton kraft pulp mill discharging wastes into this sector will reduce the dissolved oxygen concentration in the stream to an estimated minimum of 6.8 ppm once in 10 years. The dilution ratio of the mill waste to the stream flow at the minimum flow expected once in 10 years is 1-62. At this dilution there may be some reduction of the desirable fish-food organisms and impairment of fish-spawning areas in a short length of the river below the mill waste outlet. It is not believed that this effect would be sufficiently extensive to materially reduce the fish population in the stream.

Appreciable impairment of the suitability of the Clark Fork as a source for drinking water supplies would be limited principally to the sector above the junction with the Flathead. Any water supplies which might in the future take their raw water from this sector and below the waste outlets of such a mill would undoubtedly need to treat for taste and odor removal. There will be noticeable color and odor in the stream for a short distance below the mill waste outlets. It is not expected that the wastes will have a detrimental effect on the suitability of the water for irrigation purposes.

Analysis of the available information and data indicate that this sector of the Clark Fork can assimilate the wastes from a 300 ton kraft pulp mill without serious detrimental effects on existing or expected future uses of the stream water. The effluent from a 200 ton kraft pulp mill at this location would have still less effect on the water quality.

The Clark Fork and Pend Oreille River below Plains

The estimated minimum 10 year daily flow below Plains is approximately $\frac{1}{5}$ times the 10 year minimum flows expected in the Clark Fork below Missoula. It appears that the stream below Plains could assimilate the wastes from a 1,000 ton mill about as satisfactorily as the Clark Fork below Missoula can assimilate the wastes from a 200 ton mill. Assuming that a 1,000 ton mill is discharging wastes into the stream, the calculated critical or minimum dissolved oxygen concentration that would occur once in 10 years is 6.4 ppm. The dilution ratio of the wastes in the stream at the 10 year minimum flow is 1-62. The detrimental effects of the wastes from a 1,000 ton mill at most locations in this sector would probably be equivalent to those described for a 300 ton mill below St. Regis. If located above Pend Oreille Lake it would not be expected to affect the water supplies of Sand Point or Priest River. A 200 ton mill located in this sector would result in very limited pollutional effects. The only expected effect on aquatic organisms would be a possible reduction of some of the desirable bottom dwelling organisms in the sector of the stream immediately below the waste outlets where complete mixing of the wastes and the stream waters have not occurred. Other effects of the pulp mill wastes from this size mill would be insignificant.

On the basis of the available information and data, it is believed that this stream sector can assimilate the wastes from a 1,000 ton mill without significant harm to other beneficial uses of its waters.

Flathead River above the junction with the South Fork

The establishment of a 200 ton kraft pulp mill in this sector will reduce the DO concentration of the stream to an estimated minimum of 6.5 ppm once in 10 years. The dilution ratio of mill waste to stream flow at the estimated 10 year minimum flow is only 1-27. Although it appears that the oxygen resources of the stream are sufficient to assimilate the BOD of the wastes from such a mill, it is expected that at this minimum dilution there will be significant detrimental effects on the aquatic life of the stream. The expected extensive reduction of desirable fish-food organisms would appreciably reduce the fish population of the stream for some distance below the mill waste outlet. Impairment of fish-spawning areas would also be significant. The suitability of the stream as a source for drinking water supplies would be impaired in the sector extending from the mill waste outlets to Flathead Lake.

It appears that flows in the sector of the stream are inadequate to assimilate the wastes normally discharged by a 200 ton kraft pulp mill. They would have appreciable detrimental effects on the quality of the water in the stream. To prevent such pollution effects a mill of this size in this sector would need to take extreme measures to reduce the quantity of wastes and to prevent the discharge of spills or slugs of waste to the stream. In addition, treatment would very likely be necessary. These factors would probably mitigate against the selection of this sector as a site for a mill unless there were some major economic advantages of this site over the others available that would compensate for costs of needed waste treatment.

Flathead River from the junction with the South Fork to Flathead Lake

It is assumed that the proposed kraft pulp mill will be located so as to discharge wastes into the stream above the slack waters of Flathead Lake. The establishment of a 200 ton kraft pulp mill in this sector will reduce the dissolved oxygen concentration to an estimated minimum of 7 ppm once in 10 years. The dilution ratio of the mill wastes at the 10 year minimum daily flow is 1-70. At this dilution there should not be any appreciable effect on aquatic life following the complete mixing of the wastes in the river. Immediately below the mill waste outlets where there is incomplete mixing of the wastes with the stream water there may be some reduction of fish food organisms and impairment of fish-spawning areas. It is expected that this sector will be so limited that it will not affect the desirable fish population of the stream in the vicinity. There will be some impairment of the suitability of the stream as a source for drinking water supplies. As far as is known it is not presently utilized for this purpose and it is not expected that such detrimental effects will extend below Flathead Lake. Noticeable change in the appearance of the stream should be limited to the immediate sector of the waste outfall. It is not believed that there will be any effect on its suitability for use as irrigation water.

Analysis of the available information and data indicates that the wastes from a 200 ton kraft pulp mill would not have serious detrimental effects on the stream quality for other uses. This is based on the assumption that the Hungry Horse Dam will not create lower minimum daily flows in future than have occurred in the past. It also does not take into consideration possible effects of the wastes from the aluminum plant near Columbia Falls as information on the type and quantity of wastes from the aluminum plant was not readily available.

Flathead River from Flathead Lake to the junction with Clark Fork

It appears that the 10 year minimum winter daily flow and other characteristics of the Flathead in this sector are such that it may be able to assimilate the wastes from a 400 ton kraft pulp mill. It is estimated that a 400 ton mill would reduce the dissolved oxygen concentration in the stream to a minimum of 6.8 ppm once in 10 years. At the 10 year minimum daily flow the dilution ratio of the mill wastes in the stream would be 1-57. The polluttional effects of a 400 ton mill at this location would be slightly greater than the effects of a 200 ton mill in the sector from the South Fork to Flathead Lake. The significant effect on the suitability of the water as a source for drinking water would not extend below the junction with the Clark Fork. Odor and color from the wastes in the stream will be noticeable for a short distance below the mill waste outlet. The wastes should not affect the suitability of the water for irrigation use.

From the analysis of the available information and data, it is believed that a 400 ton kraft pulp mill could discharge wastes to this part of the Flathead without seriously impairing the use of the stream for either existing uses or expected future uses. It would affect downstream water supplies to the extent that treatment for taste and odor removal would probably be necessary. This sector could easily assimilate the wastes from a 200 ton kraft pulp mill.

Kootenai River from Newgate to Libby

The 10 year minimum flows of the Kootenai River in this sector are about three times as great in the summer when critical dissolved oxygen conditions are most likely to occur than in the winter. It was estimated that a 300 ton kraft pulp mill in this sector would not lower the dissolved oxygen concentration below 7.8 ppm once in 10 years. The dilution ratio of the wastes in the stream at the 10 year minimum daily winter flow would be 1-62. The effect of the wastes from this size mill on aquatic life would be limited to some reduction of the desirable fish-food organisms and impairment of fish-spawning areas in a limited distance below the mill waste outlet. Because of the relatively higher summer flows, noticeable color and odor in the stream from the wastes would be limited to a very short distance below the waste outlet.

As far as is known, there are presently no drinking water supplies utilizing this sector of the stream as a source of their water. It is reported that Libby may use it as a source in the future. If the mill is located 25 stream miles or more above Libby it is believed that taste and odor effects of the wastes on their water supply would be significant only during some periods in the

winter. It would probably necessitate some treatment for taste and odor removal in order to produce a completely satisfactory supply at Libby during all periods of the year. At present the Kootenai is not utilized for irrigation to the extent of other streams in this area. The effect of the pulp mill upon suitability of the water for irrigation use would be insignificant.

Analysis of the available information and data indicate that the Kootenai below Newgate could satisfactorily assimilate the wastes from a 300 ton kraft pulp mill. This is based on the assumption that future flows in the stream will be similar to those which have occurred during the past 20 years. Possible future diversions in Canada should be investigated before proceeding with the establishment of the mill on the stream. Although such diversions might not reduce the minimum annual flows if they decreased the average flow markedly, there would be increased pollutional effects from the wastes.

The Kootenai River extending from Libby to the Canadian Border

The stream flow and other characteristics of the Kootenai in this sector indicate that it may be able to assimilate the wastes from a 400 ton kraft pulp mill. Minimum summer stream flows are roughly three times the minimum winter stream flows. It is estimated that the wastes from a mill of this size would reduce the dissolved oxygen content to a minimum of 7.8 ppm once in 10 years. The estimated dilution of mill wastes to stream flow is 1-53 at the 10 year minimum winter flow. This is based on analysis of stream flow records both at Libby and below Bonners Ferry. The effect of the wastes from such a mill on the aquatic life would be some reduction of desirable fish food organisms and impairment of spawning areas in a relatively limited sector of the stream below the waste outlets. The suitability of downstream sectors as a source for drinking water supplies would be impaired to the extent that tastes and odors would be noticeable during low winter flows. This portion of the stream is not presently utilized as a source for public drinking water supplies but there is a possibility that Bonners Ferry may take water from it in the future. Treatment of the Bonners Ferry supply for taste and odor removal would probably be necessary during periods of low winter flow if the mill is located above the community. It is not believed that the taste and odor problem would be particularly significant during summer periods.

The available information and data indicate that this portion of the Kootenai could satisfactorily assimilate the wastes from a 400 ton kraft pulp mill but before definite consideration is given to establishment of a mill in this sector, possible upstream diversions by Canada should be investigated.

Spokane River below Coeur d'Alene Lake and above Post Falls, Idaho

The estimated 10 year minimum daily flows for this sector were based on stream flow records of the gaging station near Post Falls, Idaho which reflect the effect of major diversions for irrigation by the Spokane Valley Farms Company Canal and the Rathdrum Prairie Canal. The calculated 10 year minimum daily winter flow is 480 second feet and for the summer is 140 second feet. Extremely low flows approaching this minimum occur over an extended period of time during the late summer and fall. Flows are normally consistently low throughout September, and part of August and October. Flows of this magnitude are insufficient to assimilate the wastes from a 200 ton kraft pulp mill. At the minimum summer flow of 140 second feet the calculated critical concentration of dissolved oxygen is 1.5 ppm which is inadequate to support desirable fish life. The dilution ratio of the mill wastes to the stream flow under these conditions would be 1-11. It is very probable that this concentration of waste in the stream would be lethal to desirable fish populations. Many other aquatic organisms would be unable to exist in an extended sector of the stream below the mill wastes outlets. The sector of the Spokane affected by these diversions is unsatisfactory as a site for a 200 ton kraft pulp mill.

The Clearwater River from Kamiah to Spaulding

At the estimated minimum 10 year summer daily flow the critical dissolved oxygen concentration of the stream was calculated to be 6.9 ppm. At the 10 year minimum winter daily flow of 480 second feet the dilution ratio of the waste from a 200 ton kraft pulp mill in the stream would be 1-39. At this limited dilution there would be significant detrimental effects on desirable aquatic organisms and there may also be toxic effects to certain types of fish. Esthetic effects such as color from the waste of the pulp mill would be particularly noticeable in the stream inasmuch as it is an unusually clear and sparkling stream. The only desirable use of the stream water in this sector which would probably not be adversely affected is irrigation. This sector of the stream is considered unsuitable as a site for a kraft pulp mill.

The Clearwater below Spaulding

At the estimated 10 year minimum daily summer flow the critical dissolved oxygen concentration which would occur is calculated to be 7.5 ppm. At the 10 year minimum daily winter flow, the dilution ratio of the wastes from a 200 ton pulp mill in the stream would be 1-81. At this minimum dilution it is expected that there would be

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MONTANA AND IDAHO

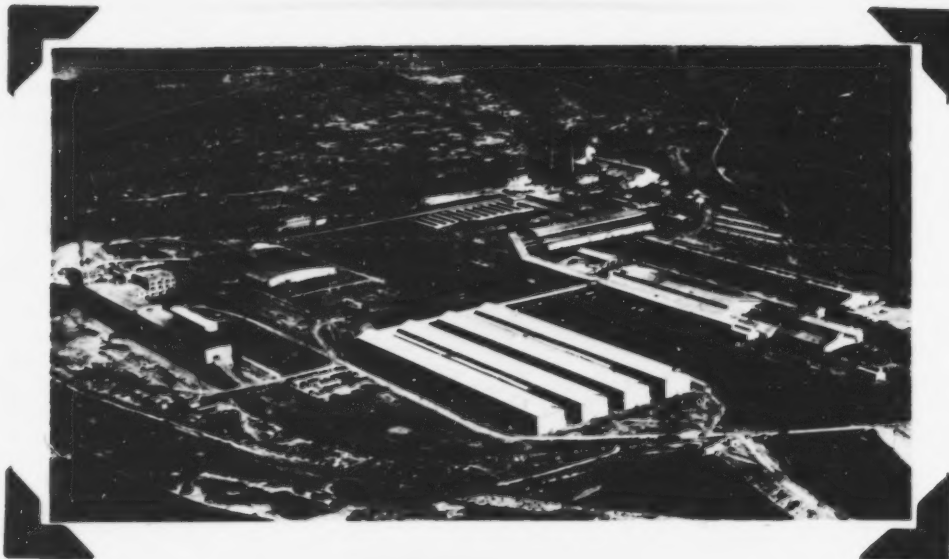


Figure 14 - Pulp and Paper Mill at Lewiston, Idaho, near the Junction of the Clearwater with the Snake River: Note Waste Water Storage Pond at Bottom Left Side of View.



Figure 15 - Manufacture of Kraft Paper at Lewiston Mill: View of Paper Machine.

some reduction of the desirable fish food organisms and impairment of spawning areas in a sector extending a few miles below the mill wastes outlets. It is probable that there would not be a significant reduction of the overall fish populations in the stream. Because of the extreme clarity of the water in this river, color introduced by the wastes would be particularly noticeable. It is not expected that there would be any detrimental effects of the quantity of the water for irrigation use. There presently is a kraft pulp mill at Lewiston which initially discharged its wastes into the Clearwater a few miles above its junction with the Snake River. A study was made of the effects of the wastes from this pulp mill on the bottom fauna of the stream for a distance of approximately two miles below the mill site's outlet at which point it discharged into the Snake River. The dilution ratio in the affected area was approximated to be 1-50. The investigation showed that there was a deterioration in the appearance of the stream below the discharge of the pulp mill effluent. The bottom fauna was also changed. It is known that local conservation groups objected strenuously to the discharge of these pulp mill wastes into this stream. Accordingly, the outlet has been extended to the Snake River. It is believed that because of the innate clarity and natural beauty of the Clearwater, sportsmen and conservation groups would be particularly sensitive to the discharge of wastes into it which would have any noticeable effects. For this reason, it would probably be desirable to select a pulp mill location on some other stream.

WASTE TREATMENT

In this study, suitability of sites has been based primarily on dilutions available in the receiving streams for effluents ordinarily to be expected from modern kraft pulp mills. The possibilities as regards waste treatment should also be reviewed. As previously indicated, the character of wastes discharged from kraft mills has greatly changed insofar as strength is concerned with improvements in the process. Water requirements have been reduced. In the past, it was not unusual to find kraft mills with salt cake losses of as much as 500 pounds per ton of pulp produced. Attending the high losses of the salt cake were problems of toxicity to aquatic life resulting from the concentrations of sulfides, mercaptans, and soaps of resins and fatty acids in the effluents. The condition has been vastly improved due to a variety of factors, such as better in-plant effluent control practices, economic considerations, and the development of controlled effluent discharge and effluent treatment methods.

Ponding of wastes is the most common procedure used for effluent disposal. In some instances, the ponds are used primarily as storage devices to hold the effluent until the volume of receiving water is sufficient for controlled release of the stored mill effluent to avoid significant impairment to stream water quality.

Controlled effluent discharge is used when stream flows are at a low level for prolonged periods of a predictable nature. Due to the physical character of these storage ponds with respect to their size and depth, plus the nature of the effluent, which is deficient in nitrogenous compounds, little or no reduction in oxygen demand of the wastes is attained upon storage. Storage periods may range in duration from a few months to as much as ten months. In view of the size of present day kraft mills and the volume of effluent per ton of product, it is apparent that the storage ponds can be very large. Their use depends on the availability of substantial land areas. Topographic characteristics of this land are important as regards costs involved for the construction of levees to make the area suitable for storage purposes.

Ponds, or lagoons, are used as effluent stabilization devices wherein appreciable reductions in strength of the wastes are attained. The extent of the reduction depends on the retention period in the pond, the presence of sufficient nitrogenous compounds to stimulate bacterial activity and the opportunity for some degree of oxygen solution, either through a large ratio of surface area to depth or by agitation. Detention periods in this type of pond may vary depending on the available volume of receiving water and the reduction in oxygen demand of the effluent required to permit its disposal without impairing the quality of the receiving water. Detention periods of 10 to 30 days are commonly used. The size of these ponds will usually be smaller than that used for storage purposes. Operation of this type of pond is generally seasonal, being used during periods of low stream flows. The effluents are discharged directly to the receiving water during higher stream flow periods.

A method that has been used with kraft effluents, especially in the south, involves passage of the effluent through oxidation channels, or canals, along with sufficient nitrogenous material to support biological growths. These microscopic organisms bring about reduction in the oxygen requirements for stabilization of such organic matter as remains in the effluent.

While the foregoing methods have been utilized satisfactorily at a number of kraft mills, successful operation has been dependent to a substantial degree on uncontrollable natural conditions. Accordingly, efforts have been directed toward development of treatment methods that would lend themselves to easy control and economical application. It was recognized that such development would tend to make available many locations now regarded as unsuitable for new mill sites from the point of view of effluent disposal.

Accordingly, such effort has been directed toward development of practical treatment processes for kraft wastes, using variations of principles employed in biological treatment of municipal sewage. Research was undertaken by the National Council for Stream Improvement of the Pulp, Paper and Paperboard Industries, Inc., using kraft effluent to which had been added certain vital nutrients essential to bacterial life. Amounts of nitrogenous and phosphorus sufficient to provide a suitable diet for organisms were introduced to enable controlled stabilization of the organic matter in the wastes by the so-called 'supplemented activated sludge process,' (9) (10).

Pilot plants utilizing the process were installed at several mills producing unbleached and bleached kraft pulp in Georgia and Virginia. The pilot plant at Covington, Virginia, completed in August, 1951, quickly demonstrated that a practical method for treating such mill wastes had been found. Reductions in oxygen demands of 80% to 90% were obtained, using mixed liquor concentrations as low as 2,000 parts per million of suspended solids with 1.0 cubic foot of air required per gallon of waste treated, and an aerator detention time as low as three hours.

Based upon many months of operating data, a full scale plant has been built for treatment of the kraft mill wastes at Covington (11). It was placed in operation in 1955. Initial operating results bear out experiences with the pilot plants. The treatment of 16 million gallons of wastes with an average oxygen demand of 140 parts per million, results in an 85% reduction of such demand.

Biological treatment is of limited effectiveness in removing the color from kraft mill wastes. Since reduction of the color of the effluent is desirable, usually for esthetic reasons, attention is being given to development of more efficient, economic means for its removal (12). Good results have been obtained with high dosages of hydrated lime. The considerable amounts of hydrous sludges produced have

proven very difficult to de-water. This has hindered practical application of the treatment. Economic considerations have also made it necessary to recover the calcium content of the sludges for re-use. Promising methods of sludge treatment employing carbonation and heat, with recovery of the calcium, are being studied (13). Findings might advantageously be given consideration in connection with the planning of new mills for installation in Montana and Idaho.

Removal of fiber from mill effluents by the most efficient methods is dictated by both economic and water pollution considerations. The modern kraft pulp mill generally uses vacuum filter "save-alls" for keeping fiber loss to sewer at a minimum. Flotation save-alls have been employed. With proper installation and operation of modern save-all equipment and water recycling facilities, fiber should not cause objectionable pollution.

Effluent diffusion facilities in streams have also been of assistance in overcoming any adverse pollution effects in proximity to the point of disposal. These facilities enable rapid dispersion in the receiving waters.

SUMMATION

The findings in this report are based on field observations of the streams and study of available data. This included the assembly and analysis of stream flow records, information on wastes discharged to streams, existing and potential water uses and water quality objectives. Estimates have been made of the effect of the wastes from pulp mills with 200 tons, or greater, daily capacity on the dissolved oxygen concentration during low stream flows in all sectors of streams which might be capable of assimilating the wastes. The probable effect of the effluents on other stream characteristics related to present and certain other possible uses has also been considered.

The need for maintaining the cleanliness of the streams in this area through suitable utilization, treatment and disposal of existing and future pollutional wastes is recognized. These streams are a valuable asset which are now utilized for the benefit and enjoyment of both residents and visitors to the region. The objective is to conserve the quality of these waters for the greatest possible use for all beneficial purposes.

The area of Montana and northern Idaho lying west of the Continental Divide has considerable renewable timber resources suitable for pulpwood which are not being utilized to the maximum possible extent at the present time. There is a desire to establish pulp mills within the region which will use timber suitable for pulpwood as a raw material.

The pulpwood available includes a considerable amount of blight damaged timber in addition to the expected annual crop of green wood. It is sufficient to supply the continuing requirements of a number of mills. Much of the available wood is very suitable for pulping by the sulphate (kraft) process. For this reason, primary consideration is currently being given to the possibility of establishing sulphate mills in this region.

The sulphate or kraft process consists of the digestion of wood chips in a sodium sulfide solution under heat and pressure which serves to separate the cellulose fibers from the other organic constituents of the wood. The spent liquor is removed from the cellulose fibers or pulp by draining and vacuum washing. It is evaporated and burned for the recovery of chemicals and the fuel value of the dissolved organic substances. The mill effluent contains chemicals, dissolved organic solids and suspended fibers.

Large quantities of water are needed in producing pulp and paper. The water required to produce a ton of kraft pulp in newer mills will range from 20,000 to 40,000 gallons. The waste produced will probably range in oxygen demand per ton of pulp from a population equivalent of 200 to 400, with carefully operated modern mills having effluents near the lower figure. The higher of these values as regards both volume and

strength was used in this study, introducing a factor of safety in the computations made in forecasting stream conditions.

A further allowance has been made in estimating the effect of the pulp mill effluents on the stream by using the minimum daily stream flow (computed from U.S.G.S. data), during both summer and winter periods, that would be expected to occur with a frequency of once in 10 years. These more critical conditions for dilution of mill effluents will exist for only limited periods on infrequent occasions.

Process and equipment improvement have resulted in a definite trend downwards in the volume and strength of unbleached kraft pulp and paper mill effluents. The strength of the wastes on an oxygen demand basis has been decreased as much as 75% by such improvements, with attendant reduction in chemical requirements. Monitoring equipment is proving of value in avoiding occasional increases in sewer losses. The work on waste reduction is nearing an irreducible minimum, however, and further removal of polluting materials necessitates consideration of treatment and disposal methods.

Even though kraft pulp mill effluents today are considerably weaker in pollutional characteristics than they were a few years ago, effluent disposal may involve more than dilution to avoid impairing the quality of the receiving waters. Such measures for treatment and disposal as have been employed in recent years with kraft mill wastes, have been directed toward reduction of waste components toxic to fish life (3-5) as well as reduction in oxygen demand. In-plant improvements have removed a large portion of toxic sulphides and mercaptans from the composite mixture of blow steam condensate, evaporator condensate, and digester relief condensate following separation of the turpentine which is usually marketed or burned.

Treatment procedures are usually necessitated by insufficient dilution being available in the receiving waters. The need and type of treatment is related to stream use. It may be seasonal or continuous. Ponding or lagooning of wastes may be employed, or other more recently developed methods for the solution of special problems, can be applied.

Stream dilutions available at pulp mill sites considered in Montana and Idaho indicate that there should be no appreciable effect on the quality of the waters for irrigation purposes (6).

Lagooning has been utilized with beneficial results in reducing the strength of kraft mill wastes, and in equalizing the flow and variations to be expected in strength of mill wastes. The use of lagoons of suitable capacity for effluents, therefore, gives flexibility in handling of wastes to avoid objectionable conditions during periods of low stream flow (7-8) and highest water temperatures. Special studies in recent years to increase the efficiency of lagoons have been conducted by the Industry through their National Council on Stream Improvement, and much information is available on performance of this method for treatment and disposal of kraft mill effluents.

Biological methods of treatment practiced by some kraft pulp and paper mills include oxidation ponds, other natural purification procedures, and the accelerated aeration process. A natural purification method of increasing popularity in the southern United States consists of passing the mill effluent down a natural or man made waterway before discharge into the receiving stream. The accelerated aeration method which consists of effluent oxidation in an aeration tank by means of biological sludge or floc was experimentally developed by the National Council for Stream Improvement. A mill at Covington, Virginia, treats all of its wastes from wood preparation through bleaching operations by the accelerated aeration process and accomplishes high reduction of the oxygen demand of the mill effluent. (9-10-11).

Progress is being made in the removal of color from kraft mill wastes (12). Color may be removed by treatment of the effluents with high dosages of hydrated lime. This treatment produces large volumes of hydrous sludges which are difficult to de-water. In view of the amount of lime required for good results, it is necessary for economic reasons to recover the calcium content of the sludges for re-use. Promising methods of the sludge treatment, employing carbonation and heat, are being developed (13).

Modern "save-all" equipment, such as vacuum filters, and water recycling systems, properly installed and operated should adequately take care of the fiber problem.

In conclusion, the observation and studies indicate the sectors of streams west of the Continental Divide in Montana and northern Idaho that appear to have the capacity to satisfactorily assimilate the wastes from kraft pulp mill installations. This preliminary survey should be followed by detailed evaluation of conditions when definite information is available covering individual mill projects. Suitable operation and treatment provisions can then be determined for each project to enable attainment of a high degree of stream cleanliness consistent with water uses (14).

Respectfully submitted by:

H. A. Anderson

H. A. Anderson, Public Health Engineer

L. P. Warrick

L. P. Warrick, Sanitary Engineer Director

TABLE 1. MINIMUM DAILY FLOWS

Location of Gaging Station	Years of Record Analyzed	Average Flows Sec.Ft.	Min. Daily Flow of Record Sec. Ft.	Estimated Min. Daily 5-yr. Flow Sec. Ft.	Estimated Min. Daily 10-yr. Flow Sec. Ft.
Clark Fork Above Missoula	21	2,582	224		
Winter	19			440	350
Summer	22			550	430
Clark Fork Below Missoula	21	4,771	388		
Winter	19			785	700
Summer	19			675	740
Clark Fork at St. Regis	34	7,256	1,000	1,250	1,140
Winter	30			1,560	1,340
Summer	30				
Flathead near Columbia Falls	22	2,797	796		
Winter	23			350	340
Summer	28			650	570
Flathead at Columbia Falls	22	8,943	798		
Winter	22			950	660
Summer	22			1,610	1,540
Flathead near Polson	43	11,230	32		
Winter	34			1,800	1,400
Summer	37			2,600	2,050
Clark Fork near Plains	34	18,460	3,200		
Winter	31			4,700	3,800
Summer	36			5,800	4,500
Pond Oreille below Z Canyon	38	25,900	2,500		
Winter	22			4,600	3,800
Summer	23			7,100	6,700
Kootenai at Haigate	20	9,610	994		
Winter	19			1,350	1,150
Summer	19			3,770	3,450
Kootenai at Libby	24	10,930	895		
Winter	25			1,460	1,310
Summer	36			4,280	3,800
Kootenai at Bennett Ferry	22	13,830	1,300		
Winter	22			1,690	1,450
Summer	22			4,700	4,400

TABLE 1. MINIMUM DAILY FLOWS (Cont.)

Location of Gaging Station	Years of Record Analyzed	Average Flows Sec. Ft.	Min. Daily Flow of Record Sec. Ft.	Estimated Min. Daily 5-yr Flow Sec. Ft.	Estimated Min. Daily 10-yr Flow Sec. Ft.
Kootenai at Port Hill	22	14,670	2,720		
Winter	23			1,830	1,500
Summer	23			4,600	4,300
Spokane near Post Falls	37	5,946	130		
Winter	37			700	480
Summer	37			350	140
Clearwater at Keniah	40	8,058	200		
Winter	40			620	480
Summer	40			870	780
Clearwater at Spaulding	24	14,730	500		
Winter	24			1,310	1,000
Summer	25			1,710	1,600

TABLE II SUMMARY OF CALCULATED STREAM DATA

	Size of Mill Tons per Day	Min. 10-yr. Flow	Temp. of Water °F	D.O. at Sat. ppm	Assumed B.O.D. of Stream ppm ult. @ 20° C.	B.O.D. Added by Existing Wastes ppm ult. @ 20° C.	B.O.D. Added by Mill Wastes ppm Ult. @ 20° C.	Total In ppm @ 20° C.
Clark Fork above Missoula	200							
Winter		350	32	13	2.0	0.15	10.6	12.75
Summer		430	72	7.8	1.5	0.12	8.6	10.2
Clark Fork below Missoula	200							
Winter		700	32	13	2.0	7.6	5.3	14.9
Fall		740	50	20.1	1.5	7.2	5.0	13.7
Summer		760	72	7.8	1.5	1.3	5.0	7.8
Clark Fork below St. Regis	300							
Winter		1,140	32	13.3	3.0	- -	4.9	7.9
Summer		1,340	72	8.1	1.5	- -	4.2	5.7
Flathead above Columbia Falls	200							
Winter		340	32	13.1	2.5	- -	10.9	13.4
Summer		570	68	8.2	1.5	- -	6.5	8.0
Flathead below Columbia Falls	200							
Winter		860	32	13.1	2.5	0.8	4.3	6.6
Summer		1,540	68	8.25	1.5	0.4	2.4	4.4
Flathead below Polson	400							
Winter		1,400	32	13.2	1.5	0.1	5.3	6.9
Summer		2,050	72	7.95	1.5	0.1	3.6	5.15
Clark Fork below Plains	1,000							
Winter		3,800	32	13.3	2.0	- -	4.9	6.9
Summer		4,500	72	8.1	1.5	- -	4.2	5.7

II SUMMARY OF CALCULATED STREAM DATA

Assumed D.O. of Stream ult. @ 20° C.	B.O.D. Added by Existing Wastes ppm ult. @ 20° C.	B.O.D. Added by Mill Wastes ppm Ult. @ 20° C.	Total B.O.D. of Stream Including Mill Wastes		Assumed self purifi- cation Constant	Crit. D.O. of Stream ppm	Crit. Time Days	Dilution Ratio
			ppm ult. @ 20° C.	ppm ult. Stream temp.				
0	0.15	10.6	12.7	7.7	1.0	11.0	7.9	28
5	0.12	8.6	10.3	10.7	2.5	5.4	2.5	35
0	7.6	5.3	11.9	8.9	1.0	10.6	7.9	57
5	7.2	5.0	13.7	10.9	2.5	8.1	3.5	60
5	1.3	5.0	7.8	8.2	2.5	6.1	1.9	60
0	--	4.9	7.9	4.7	1.0	12.1	7.9	62
5	--	4.2	5.7	5.9	2.5	6.8	2.5	72
5	--	10.9	12.4	7.4	1.0	11.1	7.9	27
5	--	6.5	8.0	8.0	2.5	6.5	2.7	46
5	0.8	4.3	6.6	4.0	0.54	11.3	10.8	70
5	0.4	2.4	4.3	4.3	1.5	7.0	3.5	124
5	0.1	5.3	6.9	4.2	1.0	12.3	7.9	57
5	0.1	3.6	5.2	5.4	2.5	6.8	2.5	83
0	--	4.9	6.9	4.1	1.0	12.2	7.9	62
5	--	4.2	5.6	5.9	2.0	6.4	2.5	73

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TABLE II SUMMARY OF CALCULATED STREAM DATA

	Size of Mill Tons per day	Min. 10 yr. Flow	Temp. of Water ° F	D.O. at Sat. ppm.	Assumed B.O.D. of Stream ppm ult. @ 20° C	B.O.D. Added by Existing Wastes ppm ult. @ 20° C.	B.O.D. Added by Mill Wastes ppm ult. @ 20° C
Pond Oreille at 2 Canyon							
Winter		3,800					
Summer		6,700					
Kootenai below Jawgate	300						
Winter		1,250	32	13.4	1.5	- -	4.8
Summer		3,450	68	8.5	1.5	- -	1.6
Kootenai below Libby	400						
Winter		1,310	32	13.6	1.5	- -	5.7
Summer		2,800	68	8.6	1.5	- -	2.0
Kootenai below Bonanza Ferry	100						
Winter		1,450	32	13.7	1.5	- -	5.1
Summer		2,480	68	8.6	1.5	- -	1.7
Kootenai at Fort Hill	400						
Winter		1,500	32	13.7	1.5	- -	4.9
Summer		2,300	68	8.6	1.5	- -	1.7
Spokane near Post Falls	200						
Winter		450	32	13.6	1.5	- -	7.7
Summer		140	72	8.2	1.5	0.3	26.5
Clearwater below Kamia	200						
Winter		480	32	13.8	1.5	- -	7.7
Summer		780	72	8.4	1.5	- -	4.8
Clearwater below Spaulding	200						
Winter		1,000	32	13.8	1.5	- -	3.7
Summer		1,600	72	8.4	1.5	- -	2.3

TABLE 11 SUMMARY OF CALCULATED STREAM DATA (Cont.)

Assumed B.O.D. of Stream ppm ult. @ 20° C	B.O.D. Added by Existing Wastes ppm ult. @ 20° C	B.O.D. Added by Mill Wastes ppm ult. @ 20° C	Total B.O.D. of Stream Including Mill Wastes		Assumed Self Purifi- cation Constant	Crit. D.O. of Stream ppm	Crit. Time Days	Dila- tion Ratio
			ppm ult. @ 20° C	ppm ult. Stream temp.				
1.5	--	4.8	6.3	3.8	1.0	12.5	7.9	32
1.5	--	1.6	2.1	2.1	2.5	7.8	2.7	200
1.5	--	5.7	7.2	4.3	1.0	12.4	7.9	33
1.5	--	2.0	3.5	3.5	2.5	7.8	2.7	175
1.5	--	5.1	6.6	4.0	1.0	12.7	7.9	39
1.5	--	1.7	3.2	3.2	2.5	7.9	2.7	170
1.5	--	4.9	6.4	3.9	1.0	12.7	7.9	41
1.5	--	1.7	3.2	3.2	2.5	7.9	2.7	170
1.5	--	7.7	9.2	5.5	1.0	11.2	7.9	39
1.5	0.3	26.5	28.3	29.6	2.5	1.5	2.5	11
1.5	--	7.7	9.2	5.5	1.0	12.3	7.9	39
1.5	--	4.8	6.3	6.6	2.5	6.9	2.5	50
1.5	--	3.7	4.2	2.5	1.0	13.1	7.9	40
1.5	--	2.3	3.8	4.0	2.5	7.5	2.5	129

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STREAM FLOW DATA

Clark Fort River above Missoula, Montana
Location: 3 miles downstream from Blackfoot River and 3 miles east of Missoula

Drainage Area: 5,710 square miles

Average Discharge: 2,562 second-feet 21 years

Extreme Maximum: 31,500 second-feet May 23, 1948

Minimum: 224 second-feet Jan. 6, 1930 (Ice jam above station)

Remarks: Records excellent except those for period of ice effect, which are fair
Flow regulated by power plant at Bonner. Several Diversions above station for irrigation.

Discharge Data in Second Feet

Year	Discharge Data in Second feet										Maximum Daily Discharge	Mean Annual Discharge	Min. Monthly	
	Minimum Daily Discharge					Min. Annual							Disch.	Month
	Nov.	Mar.	May	Sept.	Date	Disch.	Date	Disch.	Date					
1950	600	Jan. 4-5	1,460	Sept. 7	600	Jan. 4-5	18,100	3,513	1,094	Jan.				
1949	500	Dec. 25	1,000	Aug. 14	500	Dec. 25	14,800	2,934	1,270	Aug.				
1948	1,100	Mar. 11	1,280	Sept. 23	1,100	Mar. 11	28,800	4,718	1,589	Sept.				
1947	1,200	Jan. 5	856	Sept. 3	856	Sept. 3	22,000	3,887	1,595	Sept.				
1946	850	Dec. 20	1,000	Sept. 21	850	Dec. 20	9,860	2,386	1,246	Feb.				
1945	460	Dec. 25	920	Sept. 5	460	Dec. 25	9,590	2,211	674	Dec.				
1944	700	Jan. 12	668	Sept. 27	668	Sept. 27	7,710	2,032	1,070	Jan.				
1943	650	Jan. 18	1,080	Sept. 7	650	Jan. 18	17,700	4,131	1,192	Oct.				
1942	620	Jan. 5	885	Sept. 8	620	Jan. 5	16,100	2,665	1,041	Jan.				
1941	660	Dec. 16	533	Sept. 2	533	Sept. 2	5,060	1,344	889	Aug.				
1940	520	Jan. 20	714	Sept. 1-2	520	Jan. 20	5,910	1,685	715	Aug.				
1939	360	Feb. 10-12	861	Sept. 29	360	Feb. 10-12	10,400	2,199	868	Feb.				
1938	340	Jan. 31	861	Sept. 15	350	Jan. 31	19,100	2,770	830	Jan.				
1937	546	Dec. 6	320	Sept. 27	340	Sept. 27	4,830	1,429	606	Jan.				
1936	524	Dec. 20-21	474	Sept. 16	474	Sept. 16	12,300	2,234	837	Feb.				
1935	670	Jan. 19	654	Sept. 11	654	Sept. 11	9,440	1,947	699	Sept.				
1934	1,500	Feb. 27	697	Sept. 7	697	Sept. 7	14,100	3,350	875	Sept.				
1933	-	-	868	Sept. 21	-	Sept. 21	-	-	-	-				
1932	-	-	762	Sept. 21	-	Sept. 21	-	-	-	-				
1931	762	Nov. 30	368	Aug. 22	368	Aug. 22	3,700	1,430	746	Aug.				
1930	224	Jan. 7	674	Sept. 6	224	Jan. 7	8,390	2,270	679	Jan.				
1929	-	-	808	Sept. 2	808	Sept. 2	9,730	3,270	969	Sept.				

STREAM FLOW DATA

Clark Fork River below Missoula, Montana

Location: Two miles downstream from Bitterroot River and six miles west of Missoula

Drainage Area: 8,690 square miles

Average Discharge: 4,771 second-feet 21 years

Extreme Maximum: 52,800 second-feet May 23, 1948

" Minimum: 366 second-feet Jan. 16, 1935

Remarks: Records excellent except those for periods of low effect or no gage record which are fair. Gage regulation by Power Plant at Beaver Bay downstream above station for irrigation.

Discharge Data in Second-Feet									
Gage No.	Date	Min. Daily Discharge		Sept. Discharge		Min. Annual Discharge		Total Discharge	Annual Discharge
		Max.	Min.	Date	Dis.	Date	Dis.		
7-4	Jan. 4	2,060	2,060	Sept. 7	1,250	Jan. 4	1,250	32,530	6,620
7-5	" 25	2,730	2,730	Aug. 12	1,200	" 25	1,200	33,000	5,645
7-6	Feb. 7	1,910	1,910	Sept. 22	1,910	Sept. 22	1,910	52,000	5,385
7-7	Jan. 5	1,650	1,650	" 3	1,650	" 3	1,650	45,200	7,767
7-8	Dec. 20	1,460	1,460	" 21	1,280	Dec. 20	1,280	29,200	4,464
7-9	" 25	1,180	1,180	" 5	853	" 25	853	18,700	3,472
7-10	Jan. 11	1,180	1,180	" 26	1,180	Sept. 26	1,180	34,000	3,240
7-11	" 16	1,970	1,970	" 30	1,600	Jan. 16	1,600	32,600	7,686
7-12	Feb. 18	2,350	2,350	" 27	2,260	Feb. 18	2,260	29,500	5,620
7-13	Dec. 16	1,110	1,110	" 2	920	Dec. 16	920	9,780	2,599
7-14	Jan. 21	601	601	Aug. 23-24, Sept. 7	770	Jan. 21	770	73,600	3,086
7-15	Feb. 6	1,010	1,010	Sept. 29	997	Feb. 6	997	23,500	6,175
7-16	Jan. 31	1,200	1,200	" 22, 23, 25	510	Jan. 31	510	35,700	4,798
7-17	" 21	660	660	" 13	660	Jan. 21	660	11,300	2,562
7-18	Feb. 6	860	860	" 17	600	Feb. 6	600	26,700	4,277
7-19	Jan. 21	915	915	" 30	675	Jan. 21	675	19,700	3,690
7-20	" 19	1,010	1,010	" 6	-	" -	-	-	-
7-21	Dec. 16	1,210	1,210	" 18	910	Dec. 16	910	24,000	4,250
7-22	Jan. 2	662	662	" 6	662	Sept. 6	662	11,600	2,430
7-23	" 12	1,060	1,060	" 4	1,110	Jan. 12	1,110	17,500	4,220

STREAM FLOW DATA

Clark Fork at St. Regis, Montana

Location: At St. Regis, half a mile downstream from St. Regis River

Drainage Area: 10,500 square miles

Average Discharge: 7,256 second-feet 34 years

Extreme Maximum: 61,900 second-feet May 23, 1948

" Minimum: 1,000 second-feet Dec. 17, 1940

Remarks: Many diversions above station, some regulation

Discharge Data in Second-Feet

Year	Nov. Dis.	Minimum Daily Discharge		Maximum Daily Discharge		Min. Annual Discharge Date	Max. Daily Discharge	Mean Annual Discharge	Monthly Discharge	
		Mar. Date	May Dis.	Sept. Date	Min. Dis.				Min. Dis.	Mean Discharge
1929	4,844	Jan. 5-7	3,010	Sept. 9	1,900	Jan. 5-7	50,900	9,290	2,692	Jan.
1930	1,600	Jan. 25-27	2,340	Sept. 5	1,600	Jan. 25-27	47,100	7,585	2,161	Jan.
1931	2,420	Feb. 6	2,870	Sept. 23	2,420	Feb. 6	68,100	11,060	3,293	Sept.
1932	2,600	Jan. 5	2,400	Sept. 4	2,400	Sept. 4	50,600	9,543	3,445	Sept.
1933	2,000	Dec. 20	2,050	Sept. 22-23	2,000	Dec. 20	23,900	5,915	2,523	Feb.
1934	1,250	Dec. 25	1,860	Sept. 4-5	1,250	Dec. 25	23,900	5,203	2,055	Dec.
1935	1,590	Jan. 11	1,880	Sept. 29	1,690	Jan. 11	15,700	4,471	2,715	Aug.
1936	1,700	Jan. 19	2,720	Sept. 27-29	1,450	Jan. 19	40,800	10,090	2,803	Oct.
1937	1,160	Jan. 2-4	2,000	Sept. 25	1,700	Jan. 2-4	35,200	6,467	2,365	Sept.
1938	1,260	Dec. 17	1,580	Sept. 23	1,160	Dec. 17	11,700	3,420	1,664	Aug.
1939	1,260	Jan. 21-22	1,260	Sept. 1-2	1,220	Jan. 21-22	15,600	4,270	1,503	Aug.
1940	1,260	Feb. 9	1,600	Sept. 1-2	1,260	Feb. 9	26,100	5,368	1,826	Aug.
1941	1,260	Feb. 1	1,900	Sept. 21-27	1,260	Feb. 1	45,700	6,706	2,946	Nov.
1942	1,310	Aug. 2-3, 8	1,160	Sept. 16-17, 20, 22	1,160	Sept. 16-17, 20, 22	16,700	3,656	1,351	Sept.
1943	1,000	Feb. 4-5, 11-15	1,690	Sept. 2-16	1,080	Feb. 4-5, 11-15	33,000	5,701	1,592	Feb.
1944	1,920	Jan. 21-22	1,510	Sept. 21, 22, 24	1,510	Sept. 21-22, 24	27,000	5,494	1,556	Sept.
1945	1,480	Dec. 5	1,760	Sept. 8-10	1,760	Sept. 8-10	35,200	9,364	1,986	Sept.
1946	1,200	Feb. 6	2,320	Aug. 14-21	1,200	Feb. 6	50,000	7,460	2,380	Feb.
1947	1,430	Feb. 1	1,990	Sept. 16-20	1,430	Feb. 1	32,700	5,980	1,910	Jan.
1948	1,900	Dec. 24	1,260	Sept. 1-2, Aug. 20-31	1,260	Sept. 1, Aug. 20-31	15,600	2,580	1,450	Aug.

Clark Fork at St. Regis, Montana (Continued)

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Discharge Data in Second-Feet

Year	Minimum Daily Discharge				Max. Daily Discharge	Mean Annual Discharge	Min. Monthly Mean Discharge	
	Nov. Dis.	Mar. Date	May Dis.	Sept. Date			Dis.	Month
1910	1,430	Jan. 22	1,790	Sept. 5	21,800	5,430	2,300	Jan.
1911	1,050	Feb. 19-22	1,780	Sept. 6-8	130,203	6,630	1,210	Feb.
1912	1,660	Dec. 7-8	2,346	Sept. 20-23	33,100	7,266	2,570	Feb.
1913	1,390	Feb. 5, Nov. 20	2,590	Sept. 26-30	43,500	8,670	2,410	Feb.
1914	2,520	Feb. 1-2	2,340	Sept. 5	43,500	8,670	2,970	Aug.
1915	3,160	Feb. 1, Dec. 15	2,460	Sept. 9	46,400	10,800	3,650	Oct.
1916	3,160	Feb. 1, Dec. 15	2,670	Sept. 12-14	46,400	10,800	3,650	Oct.
1917	2,200	Jan. 30	2,690	Sept. 28	17,500	5,630	2,590	Jan.
1918	2,200	Jan. 30	2,980	Sept. 25	52,500	10,500	2,800	Jan.
1919	2,500	Feb. 1-9	2,620	Sept. 30	42,400	9,200	2,630	Jan.
1920	2,260	Mar. 1	2,220	Sept. 29	33,600	7,540	2,920	Feb.
1921	2,390	Feb. 27	1,890	Sept. 30				
1922								
1923								
1924								
1925								
1926								
1927								
1928								
1929								
1930								

STREAM FLOW DATA

Flathead River near Columbia Falls, Montana

Location: Ten miles northeast of Columbia and three quarters of a mile upstream from Middle Fork

Drainage Area: 1,620 square miles

Average Discharge: 2,797 second-feet. 22 years

Extreme Maximum: 29,500 second-feet. June 20, 1916

Minimum: 296 second-feet. Mar. 5, 1945

Remarks: Records excellent except those for periods of ice effect or no gage height records, which are poor. No diversion or regulation

Discharge Data in Second-Feet

Discharge Data in Second-Feet											
YEAR	Minimum Daily Discharge				Sept. Date	Min. Annual		Max. Daily Discharge	Mean Annual Discharge	Min. Monthly	
	Nov. Disch.	Mar. Date	May Dis.	Dis.		Date	Dis.			Month	
1950	600	Jan. 3	940	Sept. 25	600	Jan. 3	20,500	3,670	912	Oct.	
1949	500	Dec. 16, 17	830	Sept. 9	500	Dec. 16, 17	19,600	2,662	640	Nov.	
1948	482	Jan. 27	827	Sept. 30	482	Jan. 27	25,300	3,452	590	Mar.	
1947	350	Dec. 29, 30	1,110	Sept. 21	350	Dec. 29, 30	23,000	3,267	502	Jan.	
1946	400	Jan. 26	825	Sept. 26	400	Jan. 26	21,600	3,351	614	Feb.	
1945	330	Mar. 5-6	760	Sept. 3-4	330	Mar. 5-6	15,100	2,177	446	Feb.	
1944	350	Feb. 21-29 Mar. 1-3	572	Sept. 14	350	Feb. 21-29 Mar. 1-3	7,590	1,383	370	Feb.	
1943	350	Jan. 20	733	Sept. 30	350	Jan. 20	14,900	3,105	666	Jan.	
1942	420	Feb. 18	955	Sept. 9	420	Feb. 18	17,600	2,997	575	Mar.	
1941	360	Dec. 17	628	Sept. 1	360	Dec. 17	6,010	1,606	465	Feb.	
1940	380	Jan. 21	633	Sept. 2	380	Jan. 21	13,200	1,977	597	Jan.	
1939	325	Feb. 8	688	Sept. 24	325	Feb. 8	14,000	2,367	480	Feb.	
1938	384	Jan. 31	754	Sept. 29-30	384	Jan. 31	23,500	3,337	766	Mar.	
1937	348	Mar. 27-28	639	Sept. 22-23			13,600	2,173	325	Jan.	
1936	680	Dec. 27	555	Sept. 30	680	Dec. 27	18,200	2,475	394	Dec.	
1935	745	Oct. 20-21 Feb. 27-28	940	Sept. 30	745	Oct. 20-21 Feb. 27-28			936	Sept.	
1934	390	Jan. 14-16	3,650	Aug. 29-30					758	Sept.	
1933	482	Jan. 20	732	July 28					760	Feb.	
1932	510	Nov. 13-14	2,080	Sept. 29-30					421	Jan.	
1931			898	July 7-8					561	Jan.	
1930			655	Sept. 8-11					923	Sept.	
1929				Apr. 10-11					1,360	Aug.	
1917				Apr. 10-19					776	Dec.	

Flathead River near Columbia Falls, Montana (Cont.)

Discharge Data in Second-Feet

YEAR	Minimum Daily Discharge			Min. Annual			Max. Daily Discharge	Mean Annual Discharge	Min. Monthly	
	Nov. Discharge	Mar. Date	May Dis.	Sept. Date	Dis.	Date			Dis.	Month
1916	630	Dec. 29-31	1,440	Sept. 23-28	630	Dec. 29-31			696	Dec.
1915	640	Mar. 9-14	1,140	" 23-30, Apr. 1	640	Mar. 9-14	8,200	2,460	603	Mar.
1914	350	Feb. 5-6	1,140	Sept. 13-16	350	Feb. 5-6	13,300	2,550	623	Feb.
1913	450	Mar. 27	640	Dec. 21-22	450	Mar. 27	10,700	2,400	632	Mar.
1912				Nov. 10	350	Nov. 10	13,100	2,640	764	Nov.
1911				Sept. 28	925	Sept. 28			974	Sept.
1910										

STREAM FLOW DATA

Flathead at Columbia Falls, Montana

Location: 200 ft. downstream from highway bridge at Columbia

Falls and 5 miles downstream from Boyan Fork

Drainage Area: 4,440 square miles

Average Discharge: 6,943 second-foot 22 years

Extreme Maximum: 102,000 second-foot May 23, 1946

" Minimum: 196 second-foot Dec. 6, 1929

Remarks: Records excellent except those for periods of ice effect which are fair. No diversions.

Discharge Data in Second-Foot

Minimum Daily Discharge				Annual Date	Maximum Daily Discharge	Mean Annual Discharge	Min. Monthly Mean Discharge	
Disch.	Nov. - Mar.	Date	May - Sept.				Disch.	Month
1,900	Jan. 23	Feb. 1	2,010	Oct. 1	11,000	12,230	2,296	Oct.
1,100	Dec. 16		1,910	Dec. 16	64,500	6,217	1,269	Jan.
1,500	Mar. 10		2,900	Mar. 10	97,000	11,290	1,437	Mar.
2,200	Apr. 28-31		2,900	Apr. 28-31	77,000	11,400	2,655	Jan.
1,500	Jan. 26		2,210	" 26	65,000	10,290	2,019	Feb.
1,300	Mar. 5		2,000	Mar. 5	51,300	7,467	2,605	Dec.
1,050	Mar. 1-2		1,670	" 1-2	26,100	5,048	1,143	Feb.
2,000	Oct. 21-22		2,900	Oct. 21-22	60,300	11,180	2,525	"
1,490	Feb. 18		2,245	Feb. 15	54,300	6,565	2,156	"
1,000	Dec. 16		1,670	Dec. 16	25,200	4,030	1,356	"
300	Jan. 23		1,522	Jan. 23	40,000	5,220	1,244	Jan.
1,000	Feb. 10		1,710	Feb. 10	60,700	6,730	2,302	Feb.
1,440	Dec. 9		1,960	Dec. 9	69,600	9,425	2,012	Oct.
150	Feb. 16, Jan. 29		2,660	Feb. 16, Jan. 29	45,300	6,920	905	Feb.
699	Jan. 28		1,500	Jan. 28	67,600	8,007	1,113	Dec.
1,610	" 21		2,770	Oct. 11-12	67,600	9,662	2,210	Sept.
2,900	Mar. 10-12		2,660	Sept. 27	56,600	12,900	1,909	"
1,510	Jan. 18		2,060	Jan. 18	16,600	12,200	1,110	Feb.
1,110	" 28-31		2,200	" 21-31	46,100	10,700	1,340	Jan.
1,320	" 21		1,610	" 23	56,600	6,420	1,710	"
600	Dec. 10		1,140	Dec. 10	31,000	7,120	2,290	Nov.
1,410	Jan. 31		1,660	Jan. 31	"	7,500	1,530	Feb.
"	"		2,170	"	"	"	"	"

STREAM FLOW DATA

Flathead River near Polson

Location: One half mile below Kerr Dam and six miles below Polson

Drainage Area: 6,990 square miles

Average Discharge: 11,230 second-feet 43 years

Extreme Maximum: 42,100 Second-feet May 29, 30 1925

" Minimum: 32 second-feet April 12, 1936

Remarks: Records excellent. Several small diversions from tributaries above Flathead

Lake. Flow regulated since April 1938 by Flathead Lake. Flow of South Fork

Tributary will be regulated by Hungry Horse Dam.

Discharge Data in Second-Feet

YEAR	Minimum Daily Discharge			Max. Daily Discharge		Mean Annual Discharge	Minimum Monthly Mean Discharge	
	Nov. Disch.	Mar. Date	May Disch.	Sept. Date	Min. Annual Disch. Date		Disch. Month	Disch. Month
1950	2,970	Dec. 4	1,730	Sept. 24	1,730 Sept. 24	14,910	4,130	Sept.
1949	2,690	Nov. 7	2,600	Aug. 7	1,440 Oct. 3	9,841	2,659	"
1948	3,650	Mar. 28	1,560	Sept. 26	1,560 Sept. 26	14,223	3,966	Oct.
1947	3,500	Nov. 4	4,140	Aug. 21	3,180 Oct. 27	13,620	4,172	"
1946	4,140	" 19	3,980	July 28	3,980 July 28	12,380	4,327	"
1945	4,070	" 24	3,460	Aug. 15	3,460 Aug. 15	8,713	3,970	Sept.
1944	2,470	Feb. 13	3,270	July 16	2,470 Feb. 13	5,912	3,654	Feb.
1943	2,480	Mar. 28	4,140	Aug. 12	2,480 Mar. 28	13,560	4,255	Mar.
1942	2,420	" 29	4,060	Sept. 6	1,910 Apr. 5	10,740	3,673	Mar.
1941	400	Dec. 8	2,190	" 2	400 Dec. 8	5,197	3,466	Dec.
1940	736	Mar. 3	3,870	" 22	736 Mar. 3	6,771	2,822	Mar.
1939	2,140	Dec. 31	2,950	Aug. 6	2,140 Dec. 31	10,060	2,649	Nov.
1938	1,700	Dec. 26	1,380	" 3-4	32 Apr. 12	8,637	2,708	Oct.
1937	1,430	Dec. 18	2,870	Sept. 29	1,430 Dec. 18	7,988	1,880	Dec.
1936	1,840	Feb. 13-15	2,570	Sept. 28	1,840 Feb. 13-15	9,617	1,912	Feb.
1935	2,140	Nov. 1-3	3,510	Sept. 27-30	2,430 Oct. 27	12,430	2,792	Oct.
1934	5,880	Mar. 22-23	2,760	" 27	2,760 Sept. 27	15,860	3,600	Sept.
1933	3,140	Mar. 22-23	4,490	" 29	3,020 Oct. 15	14,100	3,190	Mar.
1932	2,140	Feb. 2-5	3,780	" 30	2,140 Feb. 2-5	11,900	2,360	Feb.
1931	2,400	Jan. 23-27	2,950	" 30	2,400 Jan. 23-27	7,630	2,540	Jan.
1930	1,540	" 22	3,200	" 18, 21	1,540 " 22	6,800	1,870	"
1929	2,660	Feb. 28-Mar.	3,070	" 29, 30	2,660 Feb. 28-Mar.	9,360	2,730	Feb.
1928	-	Mar. 22-23	4,540	" 30	"	17,100	5,300	"
1927	3,880	Mar. 22-23	7,550	" 11-12	3,800 Apr. 4-7	17,800	4,020	Mar.

Flathead River near Polson (Cont.)

Discharge Data in Second Feet

YEAR	Minimum Daily Discharge		Sept.		Min. Annual		Max. Daily Discharge	Mean Annual Discharge	Minimum Monthly	
	Nov. Disch.	Mar. Date	May Disch.	Date	Disch.	Date			Mean Discharge	Month
1926	-	-	3,240	Aug. 31	-	-	29,300	7,510	2,200	Feb.
1925	-	-	5,300	Sept. 20-30	-	-	-	-	-	-
1924	2,420	Dec. 25	3,290	" 30	2,420	Dec. 25	47,000	10,000	2,640	Jan.
1923	2,330	Jan. 14	3,800	" 29-30	2,330	Jan. 14	55,900	11,700	2,460	Mar.
1922	2,700	Mar. 15-18	3,600	" 28-30	2,700	Mar. 15-18	50,400	10,900	2,770	Mar.
1921	3,010	Feb. 11-12	3,650	" 30	3,010	Feb. 11-12	62,000	13,900	3,250	Feb.
1920	1,360	Dec. 9-11	4,020	" 12	1,360	Dec. 9-11	44,200	9,460	2,510	Mar.
1919	2,070	Jan. 12-26	2,490	" 30	2,070	Jan. 12-26	46,200	6,710	2,250	Jan.
1918	2,310	Dec. 19-20	3,680	" 30	2,310	Dec. 19-20	56,400	12,100	2,610	Nov.
1917	2,000	Mar. 12	3,740	" 30	2,000	Mar. 12	59,100	12,600	2,240	Mar.
1916	2,900	Feb. 20	5,700	" 30	2,900	Feb. 20	74,700	16,300	3,040	Feb.
1915	2,310	Mar. 10-14	4,500	" 15	2,310	Mar. 10-14	21,000	6,560	2,490	Mar.
1916	2,400	Jan. 26	3,740	" 19-20	2,400	Jan. 26	43,000	9,250	2,690	Mar.

STREAM FLOW DATA

Clark Fork near Plains, Montana

Location: Two miles upstream from Plains and six miles downstream from Flathead River

Drainage Area: 19,900 square miles

Average Discharge: 16,460 second-feet. 34 years

Extremes: Maximum 134,000 second-feet June 5, 1948

Minimum 3,200 second-feet Feb. 8, 1936

Remarks: Records excellent except those for periods of ice effect or no gage height record, which are fair. Many diversions above station for irrigation. Some regulation by Flathead Lake.

Discharge Data in Second-Feet

Year	Minimum Daily Discharge			Max. Daily Discharge			Mean Annual Discharge			Min. Monthly Mean Discharge		
	Nov. Dis.	Mar. Date	May Dis.	Sept. Date	Min. Dis.	Annual Date	Max. Dis.	Annual Dis.	Annual Dis.	Min. Dis.	Mean Dis.	Monthly Dis.
1930	8,000	Jan. 6	7,130	Sept. 25	7,130	Sept. 25	110,000	24,910	24,910	8,852	8,852	Sept.
1931	6,400	Dec. 18	4,960	Sept. 6	4,960	Sept. 6	95,700	18,090	18,090	6,269	6,269	Sept.
1932	8,700	Mar. 22	6,500	Sept. 27	6,500	Mar. 22	133,000	26,470	26,470	8,426	8,426	Sept.
1933	9,400	Nov. 15	6,200	Sept. 5	7,950	Oct. 1	104,000	21,040	21,040	9,051	9,051	Sept.
1934	7,260	Nov. 24	7,360	July 30	7,070	Oct. 8-11	70,900	18,620	18,620	7,341	7,341	Oct.
1935	5,710	Dec. 24	8,450	July 31	5,640	Dec. 24	73,900	14,270	14,270	6,593	6,593	Sept.
1936	5,600	Feb. 26	6,320	Sept. 2	5,600	Feb. 26	35,400	10,630	10,630	6,320	6,320	Feb.
1937	7,130	Nov. 13-14	10,000	Sept. 23	6,680	Oct. 6	91,300	24,470	24,470	7,266	7,266	Oct.
1938	6,320	Mar. 30	6,570	Aug. 29	6,320	Mar. 30	73,000	17,590	17,590	7,656	7,656	Sept.
1939	4,600	Jan. 29	5,420	Sept. 1-2, Aug. 20, 21	4,600	Jan. 29	47,200	11,310	11,310	5,845	5,845	Aug.
1940	3,450	Dec. 10	3,990	Sept. 3	3,456	Dec. 10	31,500	8,845	8,845	6,034	6,034	Dec.
1941	5,200	Feb. 9	5,600	Aug. 9	5,200	Feb. 9	68,000	15,630	15,630	6,074	6,074	Nov.
1942	4,500	Jan. 31-1	4,920	Aug. 5-6	4,500	Jan. 31, Feb. 1	86,900	16,920	16,920	5,014	5,014	Oct.
1943	--	--	4,460	Sept. 23	--	--	50,000	12,136	12,136	3,344	3,344	Jan.
1944	3,200	Feb. 8	5,150	Sept. 28	3,200	Feb. 8	60,800	16,060	16,060	4,083	4,083	Jan.
1945	7,050	Dec. 31	5,570	Sept. 29-30	5,450	Oct. 6-15	70,200	17,490	17,490	5,031	5,031	Oct.
1946	--	--	5,450	Sept. 17-19	5,450	Sept. 17-19	76,800	25,460	25,460	5,718	5,718	Sept.
1947	--	--	6,050	Sept. 30	--	--	119,000	22,200	22,200	6,020	6,020	Oct.
1948	4,050	Jan. 30	6,470	Sept. 30	4,050	Jan. 14	83,600	14,800	14,800	4,540	4,540	Jan.
1949	6,470	Nov. 30	4,200	Sept. 4-6	4,200	Sept. 4-6	47,300	11,400	11,400	6,200	6,200	Aug.

Clark Forks near Plains, Montana (cont.)

Year	Minimum Daily Discharge				Max. Daily Discharge	Near Annual Disch.	Min. Annual Dis. Date	Max. Annual Dis. Date	Min. Monthly Mean Dis. Dis.	Monthly Discharge Month
	Nov. Dis.	Mar. Date	May Dis.	Sept. Date						
1920	3,260	Jan. 10	5,840	Sept. 7	47,300	24,000	Jan. 10	Jan. 10	4,340	Jan.
1921	4,370	Feb. 7	5,420	Sept. 20-21	66,400	15,200	Feb. 7	Feb. 7	4,970	Feb.
1922	7,740	Feb. 15	12,200	Sept. 2-2	117,000	26,700	Feb. 15	Feb. 15	5,420	Feb.
1923	6,000	Jan. 27-31	7,740	July 21	16,800	12,600	Jan. 27-31	Jan. 27-31	6,360	Jan.
1924	-	Jan. 28-28	9,720	Sept. 27-30	-	-	-	-	-	-
1925	5,650	Dec. 31	5,950	Sept. 30	79,200	16,000	Dec. 31	Dec. 31	5,610	Jan.
1926	4,900	Dec. 9	6,600	Sept. 30	94,300	12,500	Dec. 9	Dec. 9	5,670	Dec.
1927	4,850	Feb. 5-7	7,200	Sept. 27-30	113,000	12,500	Feb. 5-7	Feb. 5-7	5,640	Feb.
1928	7,030	Feb. 11	7,030	Sept. 10-10	99,000	22,700	Feb. 11	Feb. 11	6,000	Sept.
1929	-	-	6,800	Sept. 12-15	-	-	-	-	-	-
1930	-	-	5,200	Sept. 30	-	-	-	-	-	-
1931	5,650	Dec. 24	6,800	Sept. 29-30	99,500	24,100	Dec. 24	Dec. 24	6,196	Oct.
1932	-	-	9,030	Sept. 12-14	-	-	-	-	-	-
1933	6,850	Mar. 10-17	13,300	Sept. 30	37,400	15,600	Mar. 10-17	Mar. 10-17	7,180	March
1934	5,970	Feb. 6-7	9,350	Sept. 15	67,000	17,300	Feb. 6-7	Feb. 6-7	7,360	Feb.
1935	6,240	Mar. 27-28	8,420	Sept. 26-30	115,000	24,100	Mar. 27-28	Mar. 27-28	7,030	March
1936	5,290	Mar. 10	-	-	-	-	-	-	-	-
1937	6,020	Feb. 8-10	-	-	-	-	-	-	-	-

STREAM FLOW DATA

Pend Oreille River below Z Canyon, near Metalise Falls, Washington
 Locations: 3/4 of a mile downstream from Z Canyon and 1-1/2 miles south of the international boundary

Drainage Area: 25,200 square miles
 Average Discharge: 25,900 second-feet 3t years
 Extreme Maximum: 171,300 second-feet June 13, 1946
 " Minimum: 2,500 second-feet Dec. 12, 1919

Remarks: Many small diversions from tributaries for irrigation. Flow affected by natural storage in Pend Oreille Lake and some regulation by Kerr Dam.

YEAR	Minimum Daily Discharge			Minimum Annual			Maximum Daily Discharge	Mean Annual Discharge	Min. Monthly		Remarks
	Nov. Disch.	Mar. Date	May Disch.	Sept. Date	Disch.	Date			Mean Discharge	Discharge Month	
1950	11,700	Nov. 1-5	11,000	Sept. 29-30	8,190	Oct. 2	127,800	35,650	10,780	'Oct.	
1949	9,000	Dec. 26	8,300	Sept. 18	8,300	Sept. 18	104,200	26,190	8,921	'Sept.	
1948	12,000	Feb. 7	10,600	Sept. 30	10,600	Sept. 30	171,100	37,970	12,640	'Sept.	
1947	12,500	Nov. 16	11,800	Sept. 21-23	10,100	Oct. 3	107,000	32,620	12,450	'Sept.	
1946	10,500	Nov. 9	10,200	Sept. 22	9,160	Oct. 19	88,000	27,140	10,890	'Sept.	
1945	7,510	Dec. 25	8,050	Sept. 18	7,510	Dec. 25	79,500	20,250	8,656	'Oct.	
1944	8,050	Mar. 7	7,640	Sept. 15	7,640	Sept. 15	38,100	14,540	8,140	'Oct.	
1943	9,210	Jan. 18	12,300	Sept. 30	8,820	Oct. 13	103,000	32,750	9,262	'Oct.	
1942	12,300	Mar. 23	10,300	Sept. 26-30	10,300	Sept. 26-30	70,300	25,120	11,070	'Sept.	
1941	5,930	Dec. 20	7,880	Sept. 7	5,930	Dec. 20	32,000	13,680	8,715	'Oct.	
1940	4,850	Jan. 27	7,180	Sept. 2	4,850	Jan. 27	56,600	16,930	7,598	'Sept.	
1939	5,000	Feb. 10	8,700	Sept. 12	5,000	Feb. 10	76,400	21,090	8,116	'Dec.	
1938	7,030	Nov. 7	9,740	Sept. 5	6,970	Oct. 3	96,500	25,350	7,258	'Oct.	
1937	3,500	Jan. 20	7,090	Sept. 30	3,500	Jan. 20	59,900	16,760	4,627	'Jan.	
1936	3,800	Feb. 20	7,410	Sept. 26-30	3,800	Feb. 20	87,200	21,460	4,585	'Feb.	
1935	7,500	Jan. 20	8,020	Sept. 29-30	6,710	Oct. 1-2	85,500	25,210	7,744	'Oct.	
1934	16,100	Nov. 1	6,710	Sept. 28-30	6,710	Sept. 28-30	994,400	36,270	8,254	'Sept.	
1933	7,840	Feb. 9	11,100	Sept. 30	7,840	Feb. 9	137,000	30,800	8,330	'Oct.	
1932	5,000	Feb. 2-4	8,960	Sept. 27-30	5,000	Feb. 2-4	98,000	26,800	6,270	'Dec.	
1931	6,450	Jan. 7-12	6,270	Sept. 30	6,270	Sept. 30	51,500	15,400	6,640	'Sept.	
1930	4,350	Jan. 11	7,390	Sept. 25-26	4,350	Jan. 11	50,900	17,400	5,550	'Jan.	
1929	---	---	7,010	Sept. 29-30	---	---	74,500	19,300	6,630	'Feb.	
1928	14,500	Mar. 7	12,100	Sept. 29-30	12,100	Sept. 29-30	137,000	38,200	14,700	'Sept.	

STREAM FLOW DATA

Kootenai River at Newgate, British Columbia

Location: 0.7 miles northwest of Newgate and 0.9 mile north of international boundary

Drainage Area: 7,660 square miles

Average Discharge: 9,610 second-feet 20 years

Extreme Maximum: 98,200 second-feet May 28, 1948

" Minimum: 994 second-feet Feb. 7, 1936

Remarks: Records are excellent except for periods of ice effect or no gage height record which are fair. Records give total flow of main channel and slough.

Discharge Data in Second-Feet

F.R.	Minimum Daily Discharge				Sept. Date	Min. Annual Dis.		Max. Daily Discharge	Mean Annual Discharge	Min. Monthly Mean Discharge	
	Nov. Dis.	Mar. Date	May Dis.	Dis.		Dis.	Date			Dis.	Month
930	1,770	Jan. 30	4,800		Sept. 24	1,770	Jan. 30	70,400	11,300	2,240	Feb.
931	1,500	Dec. 25	4,260		Sept. 30	1,800	Dec. 25	48,100	6,070	2,360	Dec.
932	1,910	Feb. 10	4,110		" "	1,910	Feb. 10	91,900	13,700	2,520	Feb.
933	1,740	Dec. 28	5,570		" "	1,740	Dec. 28	62,000	10,900	1,850	Jan.
934	1,820	Dec. 25	6,010		" "	1,820	Jan. 25	65,000	11,500	7,400	Sept.
935	1,440	Dec. 26	4,320		" "	1,440	Dec. 26	40,900	7,090	1,660	Feb.
936	1,670	Jan. 11	4,150		" "	1,670	Jan. 11	26,900	6,110	1,960	March
937	1,650	Jan. 19	4,340		" "	1,650	Jan. 19	45,100	10,800	2,360	Jan.
938	2,160	Feb. 18	6,860		" "	2,160	Feb. 18	57,100	12,100	2,450	March
939	1,770	Feb. 17	5,020		Aug. 23	1,770	Feb. 17	23,300	6,950	2,120	Feb. 6
940	1,590	Jan. 23	4,470		Sept. 2	1,590	Jan. 23	43,600	8,150	2,240	Jan.
941	1,260	Feb. 9	3,910		" "	1,260	Feb. 9	37,200	8,300	1,870	Feb.
942	1,850	Dec. 10	4,250		" "	1,850	Dec. 10	66,800	11,000	2,370	April
943	1,160	Jan. 6	3,800		" "	1,160	Jan. 6	37,800	7,160	1,570	Jan.
944	994	Feb. 7	3,170		" "	994	Feb. 7	49,100	7,540	1,540	Feb.
945	1,580	Jan. 20	3,980		" "	1,580	Jan. 20	45,200	10,000	2,610	Jan.
946	2,650	Feb. 26	3,560		" "	2,650	Feb. 26	63,400	12,700	3,550	Feb.
947	1,200	Dec. 20	6,350		" "	1,200	Dec. 20	60,000	11,600	2,190	Feb.
948					" "			60,500	10,300	1,800	Jan.
949					" "			32,800	6,190	1,870	Feb.
950	1,500	Jan. 2	3,600		" "	1,500	Jan. 2				

STREAM FLOW DATA

Kootenai River at Libby, Montana

Location: 1,800 feet downstream from highway bridge at Libby and one mile downstream from Libby Creek

Drainage Area: 10,240 square miles

Average Discharge: 10,930 second-feet. 24 years

Extreme Maximum: 130,000 second-feet. June 21, 1916

Minimum: 695 second-feet. Jan. 11, 1930

Remarks: Records excellent except for those periods of ice effect or no gage height records, which are poor; no known diversion or regulation above station.

Discharge Data in Second-Feet

Year	Discharge Data in Second-Feet										Max. Daily Discharge	Mean Annual Discharge	Min. Monthly Mean Discharge	
	Minimum		Daily Discharge		Min. Annual		Dis.	Month						
	Nov. Dis.	Mar. Date	May Dis.	Sept. Date	Dis.	Annual Date								
1950	1,900	Jan. 15	5,010	Sept. 25	1,900	Jan. 15	78,900	13,680	2,535	Jan.				
1951	2,000	Dec. 25	4,600	Sept. 30	2,000	Dec. 25	62,300	10,920	2,726	Dec.				
1952	2,200	Feb. 10-11	5,610	Sept. 30	2,200	Feb. 10-11	109,000	16,360	3,246	Feb.				
1953	2,000	Dec. 30-31	6,600	Sept. 20	2,000	Dec. 30-31	73,400	13,210	3,224	Jan.				
1954	1,980	Jan. 1-5	6,600	Sept. 29	1,980	Jan. 1-5	73,400	13,280	2,733	Feb.				
1955	1,390	Jan. 27	4,930	Sept. 30	1,390	Feb. 1	51,600	8,642	2,265	Dec.				
1956	1,650	Feb. 1	4,640	Sept. 14	1,650	Feb. 1	27,800	6,867	2,423	Jan.				
1957	1,400	Jan. 19	4,890	Sept. 30	1,400	Jan. 19	49,400	12,810	2,751	Jan.				
1958	2,400	Feb. 24	6,420	Sept. 30	2,400	Feb. 24	67,000	13,430	3,261	Feb.				
1959	1,710	Dec. 14	5,770	Sept. 2	1,710	Dec. 14	25,800	7,647	2,417	Feb.				
1960	1,700	Dec. 23-24	4,630	Sept. 2	1,700	Dec. 23-24	47,600	6,970	2,602	Jan.				
1961	1,230	Dec. 29	4,380	Sept. 29	1,230	Dec. 29	110,400	9,531	2,312	Feb.				
1962	1,800	Dec. 10	4,740	Sept. 29-30	1,800	Dec. 10	78,800	12,440	2,820	Feb.				
1963	1,230	Jan. 5-6	4,260	Sept. 29-30	1,230	Jan. 5-6	46,800	6,731	1,764	Jan.				
1964	1,800	Dec. 22	3,300	Sept. 24	1,800	Dec. 22	51,800	11,640	1,725	Feb.				
1965	1,800	Jan. 23	4,500	Sept. 30	1,800	Jan. 22	51,600	11,960	3,590	Dec.				
1966			4,260	Sept. 30										
1967	1,320	Feb. 9	5,120	Sept. 27-30	1,320	Jan. 17	61,400	11,900	2,090	Jan.				
1968	1,520	Jan. 17	4,020	Sept. 29-30	1,520	Feb. 17	40,600	7,430	2,360	Feb.				
1969	1,990	Feb. 17	4,690	Sept. 29-30	1,990	Mar. 1	50,700	9,960	2,420	Jan.				
1970	2,160	Mar. 1	4,090	Sept. 30	2,160		56,600	9,330	2,460	Jan.				
1971			4,250	Sept. 29-30										
1972														
1973														
1974														
1975														
1976														
	2,720	Nov. 30												

Kootenai River at Libby, Montana (Cont.)

YEAR	Minimum Daily Discharge				Min. Annual Dis.	Annual Date	Max. Daily Discharge	Mean Annual Discharge	Min. Monthly Mean Discharge	
	Nov. Dis.	Mar. Date	May Dis.	Sept. Date					Dis.	Month
1925			5,970	Sept. 23	4,000	Oct. 25, 31	5,220	4,320		
1924			4,240	Sept. 30						
1923			4,690	Sept. 30						
1922			4,750	Sept. 30						
1921			5,140	Sept. 17						
1920			7,070	Sept. 10						
1919	2,160	Feb. 27	5,140	Sept. 27	2,160	Feb. 27	79,800	12,700	3,430	Feb.
1918	1,960	Dec. 14	5,820	Sept. 30	1,960	Dec. 14	75,600	11,660	3,560	Feb.
1917			5,970	Sept. 27-30						
1916			7,890	Sept. 30						
1915			5,970	Sept. 18-30				10,200	2,790	Feb.
1914	1,690	Feb. 7	6,280	Sept. 12-17	1,690	Feb. 7	56,900	12,600	3,130	Feb.
1913	2,040	Feb. 9	7,890	Sept. 19	2,040	Feb. 9	77,300	13,200	2,990	Feb.
1912			2,850	Dec. 23-30						

STREAM FLOW DATA

Kootenia River at Bombers Ferry, Montana

Location: At highway bridge at Bombers Ferry.

Drainage Area: 13,000 square miles

Average Discharge: 13,630 second-feet 22 years

Extreme Maximum: 139,000 second-feet May 27, 1946

" Minimum: 1,300 second-feet Feb. 8, 1936

Remarks: Records excellent except for periods of ice effect which are
fair backwater from lockstony lake usually present at Bombers
Ferry. No diversion or regulation above station.

Discharge Data in Second-Feet

Year	Minimum Daily Discharge				Max. Annual		Mean Annual	Min. Monthly	
	Nov.	May	Sept.	Jan.	Jan.	Feb.		Mean	Max.
1930	2,400	Jan. 15-16	Sept. 25	Jan. 15-16	2,400	Jan. 15-16	17,570	3,700	Jan.
1931	2,460	Dec. 16	" 27	" 27	2,460	" 27	12,646	3,313	"
1932	3,500	Feb. 12-13	" 21	Feb. 12-13	3,500	Feb. 12-13	20,530	4,583	Feb.
1933	2,900	Jan. 4-5	" 21	Jan. 4-5	2,900	Jan. 4-5	16,510	4,500	Jan.
1934	2,600	" 27	" 26	" 27	2,600	" 27	16,540	2,274	Feb.
1935	2,500	Dec. 26	" 29	Dec. 26	1,900	Dec. 26	10,680	2,042	Dec.
1936	2,200	Feb. 1	" 15	Feb. 1	2,200	Feb. 1	7,132	2,012	Mar.
1937	1,900	Jan. 19	" 30	Jan. 19	1,900	Jan. 19	16,460	3,435	Jan.
1938	2,100	Feb. 24	" "	Feb. 24	3,100	Feb. 24	16,400	4,166	Feb.
1939	2,000	Dec. 17	Aug. 13-14	Dec. 17	2,300	Dec. 17	6,989	2,026	"
1940	2,000	Jan. 23-24	Sept. 2	Jan. 23-24	2,000	Jan. 23-24	10,710	2,153	Jan.
1941	1,600	Feb. 10	" 24	Feb. 10	1,600	Feb. 10	11,560	2,852	Feb.
1942	2,800	" 1	" 30	" 1	2,600	" 1	16,010	3,780	"
1943	1,400	Jan. 5-6	" 30	Jan. 5-6	1,400	Jan. 5-6	10,360	2,026	Jan.
1944	1,300	Feb. 8	" 24	Feb. 8	1,300	Feb. 8	11,130	2,016	Feb.
1945	2,000	Jan. 21	" 30	Jan. 21	2,000	Jan. 21	15,200	4,761	Dec.
1946	7,340	Mar. 1, 2, 3, 13	" 29	Sept. 29	4,620	Sept. 29	19,940	5,511	Sept.
1947	1,930	Feb. 10	" 28-29	Feb. 10	1,930	Feb. 10	17,700	3,390	Feb.
1948	2,080	Jan. 16	" 30	Jan. 16	2,080	Jan. 16	15,300	2,760	Jan.
1949	2,160	Jan. 1	" 28	" 1	2,160	" 1	6,760	2,990	Dec.
1950	2,090	Dec. 10	" 30	Dec. 10	2,090	Dec. 10	11,700	2,640	Jan.
1951	2,500	Jan. 26-31	" 29-30	Jan. 26-31	2,590	Jan. 26-31	11,200	3,030	"
1952	-	"	"	"	-	"	-	-	"

STREAM FLOW DATA

Kootenia River at Porthill, Idaho

Location: 300 feet south of international boundary at Porthill

Drainage Area: 13,700 square miles

Average Discharge: 14,670 second-feet 22 years

Extreme Maximum: 125,000 second-feet June 1, 1944

" Minimum: 1,360 second-feet Feb. 6, 1936

Remarks: Records are excellent except for those periods of ice and wind effect at Copeland which are fair. Daily discharge represents entire flow passing international boundary.

Discharge Data in Second-Feet

Discharge Data in Second-Feet											
YEAR	Minimum		Daily Discharge		Sept. Data	Min. Annual		Max. Daily Discharge	Mean Annual Discharge	Min. Monthly Mean Discharge	
	Nov. Dis.	Mar. Date	May Dis.	Dis.		Dis.	Date			Dis.	Month
1950	2,720	Jan. 15	5,710	Sept. 25	2,720	Jan. 15	125,000	19,250	4,019	Jan.	
1949	2,710	Dec. 19	4,960	" 28	2,710	Dec. 19	86,600	13,430	3,543	Jan.	
1948	3,630	Feb. 13	6,160	" 29	3,630	Feb. 13	125,000	21,120	4,928	Feb.	
1947	3,120	Jan. 5	7,450	" 22	3,120	Jan. 5	91,100	17,490	4,792	Jan.	
1946	2,870	Jan. 27	7,230	" 26	2,870	Jan. 27	83,300	17,550	3,507	Feb.	
1945	1,740	Dec. 26	5,680	" 19	1,740	Dec. 26	62,300	11,460	2,884	Dec.	
1944	2,350	Feb. 1	4,900	" 13	2,350	Feb. 1	33,300	8,205	2,997	Feb.	
1943	2,040	Jan. 19	5,250	" 29	2,040	Jan. 19	68,206	17,610	3,625	Jan.	
1942	3,440	Feb. 24	7,160	" 30	3,440	Feb. 24	81,900	17,830	4,558	Feb.	
1941	2,240	Dec. 17	6,490	" 3	2,240	Dec. 17	36,806	9,605	3,142	Feb.	
1940	2,140	Jan. 24	5,140	" 3	2,140	Jan. 24	54,600	11,370	3,391	Jan.	
1939	1,720	Feb. 10	4,900	" 29	1,720	Feb. 10	51,130	12,280	3,032	Feb.	
1938	3,100	Feb. 1	5,260	" 30	3,100	Feb. 1	91,100	17,100	4,110	Feb.	
1937	1,430	Jan. 8	4,880	" 30	1,430	Jan. 8	54,300	11,030	2,090	Jan.	
1936	1,360	Feb. 6	4,120	" 24	1,360	Feb. 6	59,600	11,760	2,192	Feb.	
1935	2,330	Jan. 21	5,290	" 29	2,320	Jan. 21	69,400	15,970	5,033	Dec.	
1934	7,470	Feb. 26	4,810	" 29	4,840	Sept. 29	69,300	21,270	10,070	Feb.	
1933	2,060	Feb. 10	5,100	" 28	2,060	Feb. 10	93,200	16,700	3,580	Feb.	
1932	2,210	Nov. 30	5,210	" 29	2,210	Nov. 30	77,200	16,200	2,660	Jan.	
1931	2,240	Jan. 1	4,700	" 28	2,240	Jan. 1	52,000	9,310	3,190	Jan.	
1930	2,290	Dec. 10	5,250	" 29	2,290	Dec. 10	61,200	12,200	2,950	Jan.	
1929	2,400	Jan. 27 thru 31	4,300	" 29	2,400	Jan. 27 thru 31	59,500	11,300	2,630	Jan.	
1928	4,140	Feb. 7	4,262	" 30	4,140	Feb. 7	4,140				

STREAM FLOW DATA

Spokane River Near Post Falls, Idaho

Location: 1 mile downstream from power plant of Washington Power Co., 1-1/2 miles downstream from Spokane Valley Forms Co., canal, and 1-1/2 miles northwest of Post Falls.

Drainage Area: 3,640 square miles

Average Discharge: 15,946 second-feet 37 years

Extreme Maximum: 50,100 second-feet Aug. 25, 1933

Minimum: 130 second-feet Aug. 23-Sept. 1, 1949

Remarks: Records good. Spokane Valley Forms Co. canal and Rathdrum Prairie Canal divert water above gauge for irrigation. Flow partly regulated by Coeur d'Alene Lake.

Discharge Data in Second-Feet

YEAR	Minimum			Daily Discharge			Min. Annual Date	Max. Daily Discharge	Mean Annual Discharge	Min. Monthly	
	Nov. Dis.	Mar. Date	May Date	Sept. Date	Oct. Date	Nov. Date				Dis.	Month
1950	1,220	Nov. 26	148	Sept. 14	Sept. 14	Sept. 14	Sept. 14	30,400	9,134	396	Sept.
1949	1,187	" 13	130	Aug. 23-31	Aug. 23-31	Aug. 23-31	Aug. 23-31	33,600	6,571	168	"
1948	2,700	" 2	168	Sept. 1	Sept. 1	Sept. 1	Sept. 1	40,200	6,578	765	"
1947	1,360	" 17	141	Aug. 10	Aug. 10	Aug. 10	Aug. 10	26,600	6,728	408	Aug.
1946	1,390	" 22	149	Aug. 29	Aug. 29	Aug. 29	Aug. 29	27,300	6,655	334	"
1945	540 ⁸	Jan. 1	203	Aug. 22	Aug. 22	Aug. 22	Aug. 22	22,600	4,565	337	"
1944	366 ²	Jan. 22	384	Aug. 19	Aug. 19	Jan. 22	Jan. 22	9,490	2,477	921	July
1943	400	Nov. 2-4	420	Sept. 21	Sept. 21	Nov. 21	Nov. 21	33,600	7,029	886	Aug.
1942	1,900	" 6	445	Sept. 12-14	Sept. 12-14	Sept. 12-14	Sept. 12-14	15,500	4,652	624	"
1941	799	" 2	444	Aug. 30	Aug. 30	Aug. 30	Aug. 30	15,200	3,086	935	July
1940	616	" 17	540	Aug. 4	Aug. 4	Aug. 4	Aug. 4	16,300	4,493	958	Sept.
1939	874	Jan. 1	832	July 9	July 9	July 9	July 9	23,200	4,472	1,137	Oct.
1938	1,000	Nov. 22	610	Aug. 19	Aug. 19	Oct. 17	Oct. 17	33,500	6,537	921	Aug.
1937	594	" 27	726	" 8	" 8	Nov. 27	Nov. 27	23,100	4,331	787	Nov.
1936	452	" "	629	July 26	July 26	Nov. 27	Nov. 27	35,400	4,950	627	Oct.
1935	906	Dec. 19	782	" 26	" 26	Oct. 1	Oct. 1	25,500	6,691	793	Oct.
1934	2,040	" 5	610	Aug. 18	Aug. 18	Aug. 18	Aug. 18	49,800	9,929	721	Sept.
1933	795	Nov. 1-2	770	Sept. 9-10	Sept. 9-10	Sept. 9-10	Sept. 9-10	28,900	7,230	839	Aug.
1932	795	Nov. 5-8	795	Aug. 28	Aug. 28	Nov. 5-8	Nov. 5-8	32,400	7,360	847	Aug.
1931	900	Nov. 4-9	820	July 17, Aug. 1	July 17, Aug. 1	Sept. 21	Sept. 21	15,600	3,530	935	July

Spokane River at Post Falls, Idaho (Cont.)

YEAR	Discharge Data in Second-Feet										Max. Daily Discharge	Mean Annual Discharge	Min. Monthly Mean Discharge		Month
	Minimum Daily Discharge					Min. Annual									
	Nov. Dis.	Mar. Date	May Dis.	Sept. Date	Min. Dis.	Annual Date	Dis.	Month							
1930	845	Dec. 31	770	July 25	770	July 25	12,000	2,960	935	Dec.					
1929	795	" 31	770	Aug. 1	770	Aug. 1	14,000	3,010	1,020	Feb.					
1928	1,890	Mar. 4	813	" 17	813	" 17	26,300	9,050	913	Sept.					
1927	2,440	Nov. 5	1,150	July 15	1,140	Oct. 20	27,900	8,060	1,420	"					
1926	1,010	Dec. 6	850	Sept. 15	630	Sept. 5	14,800	3,370	991	Aug.					
1925	870	Nov. 5	840	July 26	840	July 26	30,600	7,530	948	Oct.					
1924	1,240	" 7	895	Sept. 23	895	Sept. 23	17,400	4,240	974	Sept.					
1923	1,090	Dec. 24	878	Aug. 1	878	Aug. 1	21,000	5,780	1,030	Oct.					
1922	1,080	Feb. 13	908	Sept. 12-13	908	Sept. 12-13	24,900	5,010	973	Sept.					
1921	1,090	Nov. 15	940	Sept. 11	940	Sept. 11	25,400	7,920	1,050	"					
1920	1,090	Nov. 10	860	Aug. 25-27	860	Aug. 25-27	19,400	4,150	1,100	"					
1919	1,240	Nov. 1	1,020	Aug. 16-17	1,020	Aug. 16-17	25,800	6,340	1,130	"					
1918	960	Nov. 23-24	1,090	Sept. 1	960	Nov. 23-24	39,200	7,810	1,210	Aug.					
1917	1,380	Nov. 5	1,700	Sept. 28	1,380	Nov. 5	39,800	7,800	1,490	Oct.					
1916	1,380	" 8	1,470	" 26	1,220	Oct. 29	27,900	8,560	1,440	"					
1915	920	" 1	1,360	" 12	875	" 25	11,900	3,670	1,220	"					
1914	1,300	Dec. 25	884	" 8	884	Sept. 8	20,600	5,520	1,200	Sept.					
1913	2,520	Jan. 2	1,300	" 12	1,300	" 12	-	-	1,411	"					
1912															
1911															
1910															
1909															

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STREAM FLOW DATA

Clearwater River at Kamiah, Idaho

Locations: A quarter of a mile downstream from highway bridge at Kamiah, three quarters of a mile downstream from Lauer Creek and 6 miles downstream from South Fork. Datum of gage is 1,162.52 feet above mean sea level.

Drainage Area: 4,850 square miles

Average Discharge: 6,058 second feet 40 years.

Extreme Maximum: 99,000 second feet May 29, 1948

" Minimum 200 second-feet Jan. 8, 1937

Remarks: Records excellent except those below 4,000 second feet which are good. Some diurnal regulation at low stages caused by power plant in South Fork.

Discharge Data in Second-Feet

Year	Nov. dis.	Minimum Daily Discharge		Maximum Daily Discharge		Mean Annual Discharge	Min. Monthly Mean Discharge	
		Nov. Date	May Dis.	Sept. Date	Min. Annual Dis. Date		Dis.	Month
1950	1,600	Nov. 22	1,290	Sept. 24	1,260	55,900	1,620	Sept.
1949	1,040	Dec. 18	990	" 4	990	72,300	1,300	"
1948	2,270	Feb. 12	1,370	" 16	1,370	64,000	1,605	"
1947	2,710	Nov. 17	1,350	" 6	1,350	66,200	1,711	"
1946	1,140	Dec. 20	1,390	Aug. 29	1,140	35,200	1,694	Oct.
1945	562	" 12	979	Sept. 14-15	562	40,600	1,162	"
1944	670	" 12	979	" 13-14	670	31,500	1,074	Jan.
1943	1,430	Nov. 13	1,150	Sept. 28-30	1,010	49,700	1,186	Oct.
1942	1,850	Feb. 18	1,050	" 29	1,050	35,000	1,252	Sept.
1941	645	Dec. 15	645	Dec. 15	645	24,600	1,630	Aug.
1940	829	Nov. 18	680	Sept. 2	680	35,000	903	"
1939	1,040	" 26	818	" 27-30	818	44,000	950	Sept.
1938	741	Dec. 9	894	" 27-29	741	55,100	968	Oct.
1937	200	Jan. 6	741	" 19-20	200	32,900	860	Sept.
1936	419	Dec. 19	902	Sept. 1	419	61,500	1,050	"
1935	550	Jan. 21	859	Sept. 29-30	550	41,300	946	"
1934	2,790	Dec. 12	750	Aug. 16-31	750	42,100	806	"
1933	665	Feb. 9	1,050	Sept. 1-9	665	41,400	1,410	"
1932	750	Nov. 23	1,010	Sept. 6-9	750	72,100	1,220	"
1931	825	Dec. 27-30	735	Sept. 17-20	735	40,600	977	Aug.
1930	330	Nov. 22	970	Sept. 2-8	330	31,000	1,040	Jan.
1929	650	Jan. 6-7	890	Aug. 26-31	650	50,200	1,080	Sept.
1928	3,730	Feb. 21-25	1,260	Sept. 22-23	1,260	72,100	1,550	Sept.
				Sept. 30				

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Clearwater River at Kamiah, Idaho (Cont.)

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YEAR	Minimum Daily Discharge				Min. Annual Dis.		Min. Daily Discharge	Mean Annual Discharge	Min. Monthly Mean Discharge	
	Nov. Dis.	Mar. Date	May Dis.	Sept. Date	Dis.	Date			Dis.	Month
1927	2,050	Jan. 22	1,910	Aug. 27	1,910	Aug. 27	66,600	10,900	2,530	Aug.
1926	1,430	Nov. 24-26	1,040	Aug. 15-16	1,040	Aug. 15-16	35,900	5,660	1,400	Sept.
1925	1,780	Jan. 28	1,430	Sept. 14	1,220	Oct. 24-27	59,600	9,560	1,510	Oct.
1924	950	Jan. 1-3	950	Sept. 16-17	950	Jan. Sept.	55,900	6,310	1,140	Sept.
1923	695	Nov. 25-26	1,220	Sept. 10-26	695	Nov. 25-26	49,600	7,250	1,040	Oct.
1922	1,070	Jan. 20	960	Sept. 21	960	Sept. 21	62,400	6,320	1,220	Sept.
1921	2,510	Feb. 23	1,210	Sept. 2	1,210	Sept. 2	69,700	11,600	1,750	Sept.
1920	500	Dec. 16	2,660	May 31	500	Nov. 30	43,600	7,420	713	Dec.
1919	667	Nov. 26	667	Sept. 24-25	667	Nov. Sept.	52,800	5,990	1,010	Sept.
1918	1,320	Nov. 17	1,430	Sept. 22	1,220	Oct. 13	52,800	10,400	1,410	Oct.
1917	602	Nov. 13	1,430	Sept. 20	602	Nov. 13	70,500	10,700	1,650	Jan.
1916	1,760	Nov. 14-15	1,660	Sept. 21-22	1,660	Sept. 21-22	56,000	9,710	1,510	Jan.
1915	1,130	Jan. 26	1,320	Aug. 31	1,130	Jan. 26	26,200	5,950	1,660	Sept.
1914	950	Dec. 5-6	1,130	Aug. 19-20	950	Dec. 5-6	42,200	7,330	1,420	Aug.
1913	1,040	Jan. 6-7	1,320	Sept. 21	1,040	Jan. 6-7	76,600	10,500	1,720	Sept.
1912	2,510	Mar. 5	1,430	Sept. 1-9	1,040	Jan. 14	60,200	10,300	2,170	Sept.
1911	1,540	Mar. 1.	1,320	Nov. 13	1,320	Nov. 13	36,600	6,090	2,070	Sept.

STREAM FLOW DATA

Olaewater River at Spalding, Idaho

Location: A quarter of a mile downstream from Lapwai Creek

Drainage Area: 9,570 square miles

Average Discharge: 14,730 second-feet 24 years

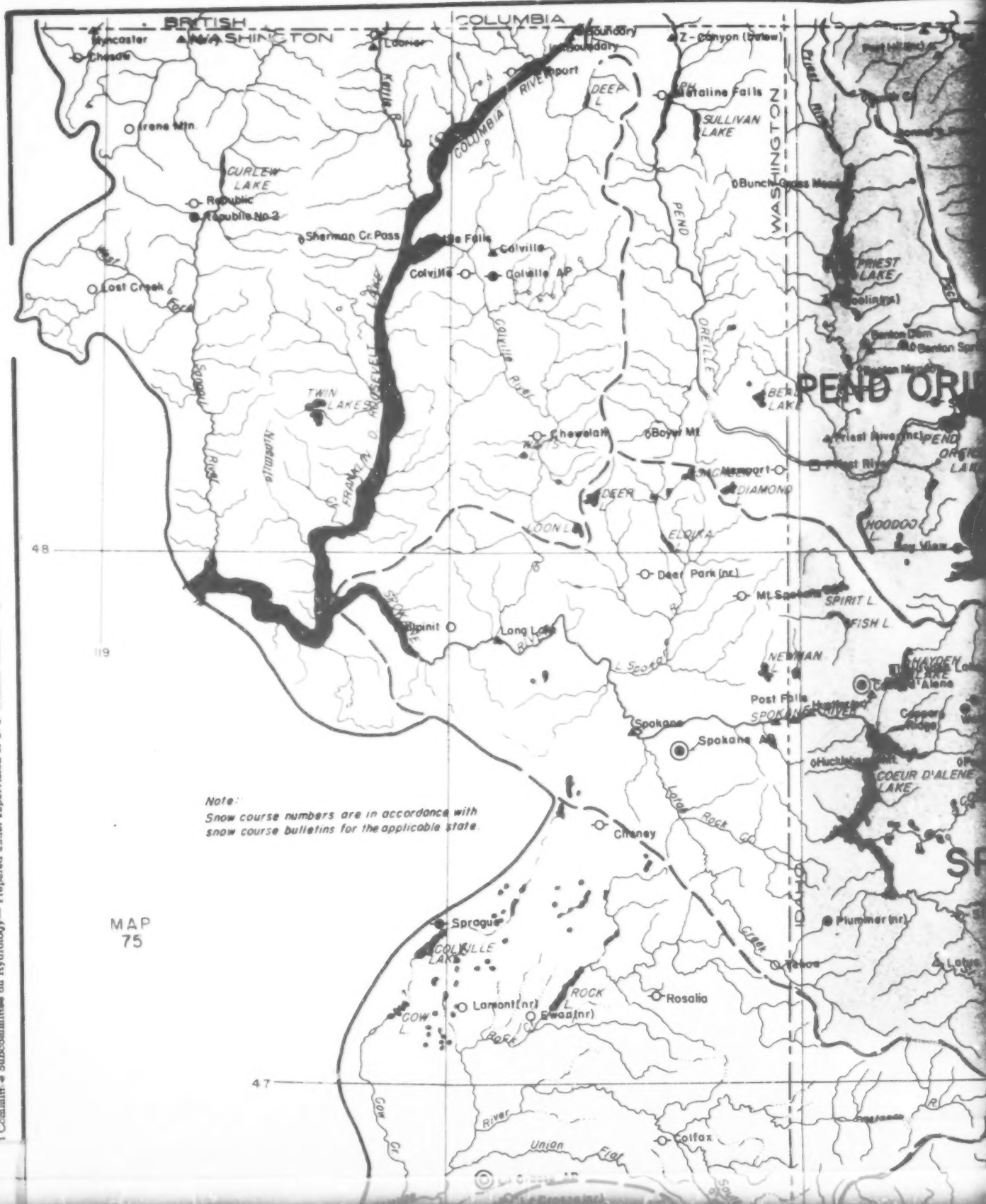
Extreme Maximum: 177,000 second-feet May 29, 1948

" Minimum: 500 second feet Jan. 9, 1937

Remarks: Records excellent except for periods of ice effect which are fair. Small diversions from tributaries. Slight diurnal fluctuation at times caused by power plant on South Fork.

Discharge Data in Second-Feet

Year	Minimum Daily Discharge				Min. Annual Disch.	Date	Maximum Daily Discharge		Mean Annual Discharge	Min. Monthly Disch.	Mean Monthly Discharge
	Nov. Disch.	Mar. Date	May Disch.	Sept. Date			Disch.	Date			
1950	2,400	Jan. 15	2,770	Sept. 2-5	2,400	Jan. 15	91,900	Jan. 15	19,740	3,441	Sept.
1949	2,600	Dec. 18	2,150	Sept. 29	7,150	Sept. 29	117,000	Sept. 29	17,190	2,631	Sept.
1948	5,550	Nov. 6	2,840	Sept. 17	2,840	Sept. 17	166,000	Sept. 17	24,440	3,339	Sept.
1947	4,850	Nov. 17	2,560	Sept. 7	2,560	Sept. 7	108,000	Sept. 7	16,450	3,356	Sept.
1946	2,650	Dec. 20	2,740	Aug. 31	2,360	Oct. 16	63,300	Oct. 16	14,840	3,075	Oct.
1945	1,540	Dec. 13	1,950	Sept. 15	1,540	Dec. 13	74,300	Dec. 13	12,260	2,336	Oct.
1944	1,680	Jan. 30	1,810	Sept. 15	1,680	Jan. 30	48,400	Jan. 30	6,556	2,363	Sept.
1943	3,020	Nov. 14	2,200	Sept. 29-30	2,020	Oct. 10	82,800	Oct. 10	19,420	2,309	Oct.
1942	4,370	Feb. 19	2,040	Sept. 30	2,040	Sept. 30	49,300	Sept. 30	12,820	2,533	Sept.
1941	1,660	Dec. 16	2,370	Aug. 21	1,660	Dec. 16	37,400	Dec. 16	9,074	3,746	Oct.
1940	1,720	Oct. 1	1,500	Sept. 3	1,500	Sept. 3	53,500	Sept. 3	11,250	1,955	Aug.
1939	2,200	Nov. 28-29	1,710	Sept. 28	1,710	Sept. 28	73,400	Sept. 28	11,450	1,962	Sept.
1938	1,920	Nov. 6	1,610	Sept. 29	1,790	Oct. 14-15	123,000	Oct. 14-15	13,970	2,057	Oct.
1937	500	Jan. 9	1,660	Sept. 21, 21	500	Jan. 9	50,900	Jan. 9	9,069	1,577	Jan.
1936	1,000	Dec. 20	1,680	Sept. 1-2	1,000	Dec. 20	101,000	Dec. 20	14,140	2,121	Sept.
1935	1,500	Jan. 21	1,720	Sept. 24-29	1,500	Jan. 21	69,400	Jan. 21	12,030	1,940	Sept.
1934	5,460	Dec. 7	1,660	Sept. 8	1,560	Sept. 8	157,000	Sept. 8	19,170	1,906	Sept.
1933	1,900	Feb. 9	2,360	Sept. 7	1,900	Feb. 9	126,000	Feb. 9	16,500	3,010	Oct.
1932	1,570	Nov. 24	2,040	Sept. 15-19	1,570	Nov. 24	114,000	Nov. 24	16,700	2,310	Oct.
1931	1,760	Dec. 9	1,510	Sept. 6	1,510	Sept. 6	66,100	Sept. 6	9,540	1,940	Aug.
1930	950	Jan. 15	1,630	Sept. 5-6	950	Jan. 15	57,000	Jan. 15	10,300	2,040	Nov.
1929	1,000	Feb. 9-10	1,900	Sept. 19-21	1,000	Feb. 9-10	73,300	Feb. 9-10	10,300	2,060	Sept.
1928	6,070	Nov. 2	2,470	Sept. 21-30	2,450	Sept. 28-30	104,000	Sept. 28-30	24,200	2,880	Sept.
1927	5,660	Nov. 5-6	3,670	Aug. 24-31	3,670	Oct. 1-3	106,000	Oct. 1-3	20,000	4,570	Aug.
1926			2,020	Aug. 17	2,020	Aug. 17				2,530	Aug.





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Note:
Snow course numbers are in accordance with
snow course bulletins for the applicable state.

MAP
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MAP
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WASHINGTON

MAP
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OREGON

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COLUMBIA RIVER BASIN

(International Boundary to Grand Coulee)

PEND ORIELLE, SPOKANE, WALLA WALLA AND LOWER SNAKE RIVER BASINS

PACIFIC COAST DRAINAGE IN WASHINGTON

Map No. 76



SPOKANE

CLARK

CLEARWATER

SEASIDE RIVER BASINS
WASHINGTON

MAP
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E

